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VOLUME II

SELF-STUDY QUESTIONNAIRE

FOR REVIEW OF

ENGINEERING PROGRAMS

1995-96 EDITION

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Submitted by

Naval Postgraduate School

June 30, 1995

to the
Engineering Accreditation Commission

SELF-STUDY QUESTIONNAIRE

FOR REVIEW OF ENGINEERING PROGRAMS

VOLUME II

NAVAL POSTGRADUATE SCHOOL, MSEE PROGRAM

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XI. OBJECTIVES and SELF-ANALYSIS

A. Preparation for evaluation

Preparation for accreditation evaluation of the institution was coordinated by the Associate Dean of Engineering, in conjunction with a Steering Group consisting of the Deans of Faculty, Research and Instruction, the three engineering Department Chairs, the Library Director, and the Computer Center Director.

The Department's portion of the preparation was coordinated by the Department Chairman and the three Associate Chairmen. The tasks were generally divided as follows:

Course content and descriptions -- Associate Chairman for Instruction. Eighty-six EC courses were reviewed by 33 different department faculty members. As part of this review, course descriptions were updated and revised to conform to a common ABET format selected for all engineering departments by the Steering Group. This effort included most of Section VII.

Curriculum requirements -- Associate Chairman for Student Programs. Curriculum requirements were analyzed and mapped into the ABET requirements by the Associate Chairman with help from two other faculty who assist him in degree program advising. This task involved all of Section XIV and parts of Section XII.

Laboratory and equipment descriptions -- Associate Chairman for Research. Laboratory space and equipment were inventoried for the data required by the Laboratory and Facilities Committee, which is led by the Associate Chairman. Faculty Laboratory Directors and the ECE Laboratory Manager were consulted to gather needed data.

Overall responsibility -- Department Chairman. The Chairman delegated tasks, assembled the document and contributed Sections XI and XV.

The entire Department was provided information on ABET requirements. Each faculty member has been involved in the self-study process.

B. Program objectives

1. The primary objective of the department's MSEE Program is to provide our students with the highest quality, most DOD-relevant graduate education available anywhere in Electrical and Computer Engineering. This goal supports the mission of the Naval Postgraduate School, which is to enhance the warfighting capabilities of US forces and its allies. This is accomplished by providing graduates with technical knowledge and skills which enable them to perform effectively in functional areas pertaining to the operation, analysis, evaluation, design and acquisition of military electronic systems.

2. The program objective is addressed through the following student educational goals:

   a. Enhanced ability to develop new technical skills and understanding through independent study.

   b. Understanding of basic concepts underlying modern system operation, including principles of electronic devices and circuits, stochastic processes, communications principles, signal processing, electromagnetic phenomena, control principles, digital and analog processes, and computers.

c. Knowledge of modern technology and trends which impact upon military systems.

d. Capability to carry out the design process including requirements determination, development of technical specifications, establishment of test and evaluation plans, incorporation of reliability and maintainability features, and evaluation of performance versus life cycle cost and other tradeoffs.

e. Analytical skills which enable the graduate to determine how systems operate; what their capabilities and limitations are; when their operation is degraded; and how to carry out, or supervise, fault isolation and repair or replacement operations.

C. Action to correct previous weaknesses

The previous report recommended that FORTRAN be supplemented or replaced by a structured language such as Pascal, C, or ADA in the refresher and basic-level programs.

The Department has replaced FORTRAN as the primary language with MATLAB, C++, and ADA. MatLab is used widely by students as a working tool for homework and thesis computations in virtually all areas except Computer Engineering. ECE offers EC1010. Introduction to MATLAB (1-1), as an optional course to students. This has been very well received and is taken by virtually all ECE students and many from other disciplines. In addition, C++ is used in upper level computer engineering courses. Development of familiarity with ADA was, until recently, required of all U.S. Navy students by our Navy sponsor (SPAWAR). This has been replaced this year by a requirement of a working knowledge of any high-level programming language, to include MATLAB, C, C++, or even FORTRAN.

The previous report recommended that EC3370, Electromechanical Energy Conversion (4-0), be renumbered at the 2000 level."

This course has been replaced with a completely redesigned course EC2270, Basic Electronic and Electrical machines (4-2), which adds a broader exposure to electronics and incorporates a laboratory experience.

The previous report found "In a few cases, the texts used may be too elementary for the course level..." and "In some situations, books that appear to be outdated are being used when newer and more appropriate books are available."

As part of the department's 1991 faculty organization into Technical Area Groups (TAG's) (to be discussed in the following section) faculty were empowered to continuously review and update course content and associate curriculum under the TAG's purview. This has led to vigorous updating and revisions of all courses in the program, including adoption of recent and appropriate textbooks as a group effort by those that teach the courses. Textbooks are typically changed every two to three years at present.

Finally, the report noted that "Purchasing is apparently somewhat of a bottleneck an a source of some frustration to faculty."

The situation has improved greatly with implementation of nearly real-time credit card purchases of smaller items and supplies (< $2,500) by the department's Supply Technician. Lengthy delays remain, however, for larger purchases, which must be routed though the NPS Supply Department. There is currently a campus level Process Action Team composed of faculty and staff who are investigating ways to further streamline the purchasing process. A recent innovation has been installation of a computer networked system for "paperless" requisition and travel functions.

D. Major developments since previous visit

1. During 1991, Faculty were organized into the following Technical Area Groups (TAG's):

Circuits/Devices (2 Faculty)	Communications (10 Faculty)
Computer Engineering (7 Faculty)	Control Systems (4 Faculty)
Electromagnetics (5 Faculty)	Optics/Acoustics (4 Faculty)
Power Systems (2 Faculty)	Radar and EW (4 Faculty)
Signal Processing (6 Faculty)	

where current primary membership is shown in parentheses. There is substantial dual and triple TAG membership elected by individual faculty. This is strongly encouraged to bond the faculty and avoid department division. TAGs were envisioned as an interlinked structure for faculty governance which would empower faculty to formulate new instructional and research initiatives while reviewing and updating the current curriculum on a continuing basis. The TAG concept was proposed to faculty and discussed and revised in a series of faculty meetings before unanimous approval. Under this charter, TAG initiated course or curriculum changes are brought before the ECE Curriculum Committee for comprehensive discussion, revision, and implementation. Major changes to degree requirements in any of the tracks are further brought before the department faculty for consideration and vote.

2. Since the last accreditation visit, 17 of the 39 faculty present in 1989 have left the department (including 9 retirements and 3 rotating military faculty). Thus, 22 of the current 44 faculty have started since the last visit. These new energetic faculty members have specialties in several areas of importance to the Department (including computer engineering, digital signal processing, electronic warfare and radar systems, control systems and robotics, and communication systems.

3. A SUN workstation based Academic Computing Lab has been established with servers and workstations located in several locations throughout the department for student, as well as in many faculty offices. In addition, a large PC lab has been established for student use. A recently established goal which is nearing completion is to have all faculty networked into the department's network, either through workstations or PCs (with ethernet card).

4. A Power Systems MSEE option has been established, with recruitment of two outstanding faculty in this area. This has led to development of course and program offerings and creation of a new Power Systems Laboratory costing over $500K.

5. Extensive capital investment has taken place to upgrade laboratory equipment using OPN (Other Procurement, Navy) funds, with the following amounts spent by fiscal year: FY90 $756K; FY91 $332K; FY92 $971K; FY93 $646K; FY94 $ 87K; FY95 $ 87K. These amounts include funds spent on the new Power Systems Lab and on establishing much of the new Academic Computing Lab.

6. Construction of several ECE faculty and staff offices was completed in 1992 at a cost of $25K. This converted wasted open bay space into useful offices which relieved severe congestion (including two occupants in some faculty offices) caused by a large increase in recruited ECE faculty during 1990. This improvement took 7 years to finally accomplish.

7. TRW made a commitment to fund a Chair position in Signals Intelligence for five years beginning in 1990 at the rate of $50K/year. This gift has been received annually by the non-profit NPS Foundation and deposited in a special account. The department has recruited the first such Chair, on loan from the National Security Agency, who is engaged in developing a new MSEE option area in Signals Intelligence.

8. Pay grades of civilian clerical staff in the department have been permitted to rise somewhat since 1989, thus partially mitigating severe recruiting and retention difficulties experienced prior to that time.

E. Plans for future development

Following several months of preparation and formulation of possible initiatives, a Strategic Planning Retreat was held by the ECE Department in January 1994. This was the first such retreat held by the department. The results of this process were the formulation of several "strategic initiatives" which form the framework for future development. Those initiatives which have since progressed towards implementation are discussed below.

1. Continuing and Professional Education Programs

This initiative seeks to exploit a large untapped market for distance learning (VTC) graduate degree programs and short courses in ECE having specific military relevance to DOD organizations and contractors. It also increases NPS visibility and military value. With sufficient student enrollment and funding, non-traditional courses can be designed to meet needs of a command or lab. Refresher Courses can bring some of our past graduates back to provide updated education. Short Courses allow increased flexibility for shortening the residency time for students. Thus far, the Naval Surface Weapons Center (NSWC) at Dahlgren, VA has been our only customer, having received two short courses this year. NSWC has also moved forward with enrollment of 20 students in our new VTC based MSEE program in Computer Engineering, which will begin this Fall. This program uses currently offered courses having NPS students present in the VTC classroom at the same time as NSWC students participate. Our distance learning initiative will be marketed vigorously to other DOD labs and installations to expand the customer base for additional MSEE tracks.

2. Electronic Warfare MSEE Option

This option area is highly relevant to combat operations in all services and is planned as a joint services program. It will also admit students from selected allied nations and is a logical candidate for a Joint Warfare Analysis curriculum track. The new option complements the operational EW curriculum through a more academically rigorous program using currently offered ECE courses and one new overview course in EW systems. This option was presented to the ECE faculty in an open forum and was approved unanimously for implementation beginning in next Fall quarter.

3. Military Robotics Interdepartmental Initiative

This is a cooperative initiative between the three engineering departments (AA, ECE, and ME) and the CS Department. A faculty working group has been formed to create an MS degree program in military robotics which incorporates existing and new courses in the areas of: rigid and articulated body dynamics; servo level and intelligent control systems; virtual reality and graphical simulation; robot/human communication; machine vision and sensor fusion; precision strike planning, and; mine countermeasures.

In addition, a Center for Military Robotics is in the planning stages which will consolidate talent in: robotic vision and sensors; computation and algorithms for autonomous missions; guidance and control systems; mechanical design of robotic manipulators, and; design of submerged, surface, air, and space vehicles.

4. Space Engineering MSEE Option

This program is being designed to meet requirements of the Space Engineering Curriculum and has emphasis on satellite payload design, with courses from the whole range of ECE. This option allows space engineering students with BSEE backgrounds to undertake the MSEE as an option, instead of the MS in Aero/Astro.

5. Signals Intelligence MSEE Option

This option will emphasize signals intelligence and cryptology and is being developed by ECE faculty with help from the new SIGINT Chair, who is funded by NSA and TRW. The principal customer, who will send students to this program, is the Naval Security Group (NSG). Other potential customers are NSA, Army, and Air Force. Two possible approaches for the Signals Intelligence MSEE Option are being investigated. Both require substantial course development.

Additional future developments which have originated since the Strategic Planning Retreat are:

6. New Laboratory Floor Space

Due to the relocation of ME Department labs from the second floor of Spanagel Hall, there will be additional space available to share between the current occupants (CS, ECE, Oceanography, and Physics Departments). An allocation plan supported by three of the four occupants (OC refusing) gives ECE about 3000 square-feet of additional space, primarily on the third floor. This space is to be used to establish new laboratories supporting the EW/Space/SIGINT initiatives, as well as new labs for Military Communications, Computer Communications Networks, and Analog VLSI. Formal allocation of the requested space has yet to come from the NPS administration.

7. Systems Engineering Masters Degree

This new initiative is being investigated by the three engineering departments in response to military needs for people educated to lead the design, acquisition and operation of increasingly complex warfighting systems. The curriculum is envisioned to be composed of three elements: (1) core analysis (mathematics, decision theory, system acquisition, etc); (2) traditional engineering study in one or more areas of specialization, and; (3) system design and simulation (to include CAD, manufacturing, reliability, survivability, etc).

F. Program strengths

The principal strengths of this program are discussed below.

A Highly-qualified and Motivated Faculty. Department faculty are highly qualified in educational background, and research or job experience. One-half of the faculty have joined the department since the last accreditation visit in 1989. Virtually all of the Department's faculty are active in research and/or consulting, and have expertise in a broad range of sub-disciplines of Electrical and Computer Engineering.

Student Maturity and Dedication. The typical entering student has completed approximately six to eight years of experience as a military officer, often in command positions, and is thus a mature individual. Entrants are screened not only for academic ability, but also for job performance. Thus, the students generally have high levels of past achievements and good prospects for future advancement. They are highly motivated to perform well and to meet expectations.

Strong Laboratory Emphasis. Most ECE courses include a laboratory session. The laboratory experience is quite important in bridging the gap between engineering theory and practice. Graduate as well as undergraduate courses feature laboratory exercises and projects supervised directly by professors, as there are no teaching assistants.

Thesis Requirement. All students receiving a graduate degree in Electrical Engineering are required to complete an acceptable thesis. The minimum time allocated to the thesis investigation for an MSEE degree is the equivalent of one quarter of full-time effort; however, the actual work is generally spread over at least three quarters. The thesis requires the student to work individually with a faculty member and provides the opportunity for in-depth independent study and practical design experience, as well as integration of course material.

Superior Laboratory Support. The Department has been successful over the years in upgrading the salaries of its technical staff positions. As a result, we are able to attract and retain highly competent Laboratory Directors, Engineers, and Computer Specialists within the Department.

Range of Option Areas and Program Flexibility. Our MSEE program allows students a wide range of choice in option areas, with seven concentrations that virtually span the entire gamut of ECE. There are extensive choices in elective courses and students can begin the program in any of the four quarters. This flexibility is designed for the convenience and benefit of our students, who most often can not select when they will arrive at or depart from NPS. In essence, there are as many curriculum matrices as there are students at any one time. This creates difficulties within the department to properly project student demand and course loads and to optimally schedule classes. The academic advising performed by three of our faculty is also made more time consuming.

User-Dedicated Computer Facilities. Students and faculty can obtain easy access to any of the various computer resources distributed within the department and across the campus, including the Amdahl 5995 campus mainframe, the Cray YMP-EL supercomputer, dozens of UNIX workstations and high-power DOS/Windows PCs. All faculty have workstations and/or PC's in their offices and virtually all students have workstations or PCs in their thesis areas and PCs at home.

Research Initiation Support. New faculty are strongly supported to perform initial research by in-house start-up funds. This Research Initiation Program provides up to two years of support, funding five months per year while providing monies to buy needed computational tools and other equipment. This initial funding is considered as "underwriting" which serves to launch the faculty member's career. New faculty are expected to locate external reimbursable funding sources at their earliest opportunity without waiting to exhaust the two years of RIP support. This program allows us to attract highly talented junior faculty applicants.

G. Program Limitations

The principal limitations of this program are discussed below.

Limited Funds for Modernization of Instructional Laboratories. Funding for modernization of the instructional laboratories comes from four sources. Operating funds to NPS come in two categories: (1) funds used to purchase items that cost more than $25,000 is called OPN (Other Procurement, Navy); (2) funds used to purchase items that are less than $25,000 are titled O&MN (Operations and maintenance, Navy). In addition, a third source of equipment is the General Purpose Test Equipment (GPTE) program. This is a Navy-wide program to systematically replace obsolete test and calibration equipment. The fourth source of support for instructional labs is equipment purchased to also support externally funded research using reimbursable research funds. Such dual purpose use is common at other institutions as well. If internal budget reductions continue, this last source may well become our only salvation from obsolescence.

The amount of OPN funding is sporadic, as can be seen from the fiscal year figures given in part D.5. of Section XI. Unfunded requests are rolled over into following years. Our unfunded list currently exceeds $1M. The drastic reductions in available OPN funds to NPS for the past two years are supposedly a result of long-range programming reductions brought about in error by the Navy. If this error continues, the department (and NPS) will rely upon increasingly obsolete laboratory equipment which will eventually fail to support an ABET accredited advanced level program.

O&MN funds have also been steadily decreasing each year, declining from about $150K in FY90 to $84K in FY95. These funds are used to support daily department operations, including purchase of supplies, copy paper and transparencies, replenishment of expendable supplies in all instructional labs, and purchase of lower cost equipment, including computers, as funds permit.

The GPTE program provides a minimal base to replace equipment used only for test and calibration in our Calibration Lab (about $15K this past year). The replacement funding is tied to the annual inventory of test equipment. The GPTE fund is administered by the ECE Laboratory Manager.

Overworked Administrative Support. It is most difficult and stressful for the small cadre of four administrative personnel (one Administrative Support Assistant, one Clerk-Typist, one Editorial Assistant, and one Supply-Travel Clerk) to meet the staggering administrative needs of 44 faculty members and 25 technical personnel. This support includes timekeeping and budgeting for instruction and all research projects, extensive copying and preparation of instructional and research presentation materials, all travel arrangements and ordering of supplies and equipment (including receipt thereof) associated with all projects, as well as dozens of other time-consuming tasks. Obtaining additional personnel to handle this heavy load is rejected by the NPS administration due to limited available budget.

Lack of Teaching Assistants. The Department has no teaching assistants. This means that faculty are responsible for teaching all laboratories and for grading reports, exams, and homework sets, thus resulting in a heavier workload over most comparable research-oriented universities.

Too Few Ph.D. Students. The faculty are expected to publish leading-edge research work while devoting long hours to advising M.S. level thesis students. Although bright and energetic, such students have only a short exposure to their research topic and consequently, with few exceptions, contribute much less to the innovative portion of the research than would a Ph.D. student. In virtually all cases, the faculty member prepares research papers and presentations without direct help from students, and shares co-authorship with students who are long gone onto the next duty assignment. This is in stark contrast to the creative leverage enjoyed by faculty at leading research universities who become the co-authors on papers written by their Ph.D. students - students who also reach a level whereby they become the creative force behind their own research.

H. Support services

1. *Library support* is excellent. The major journals are available and the book collection in Electrical and Computer Engineering is very good. The capability of performing on-line data base searches has further improved library support services. The Library floor area has been expanded since the last accreditation visit with an addition.

2. *Computer services* is a major strength of the Naval Postgraduate School, as previously discussed. An extensive network of workstations and PCs, both within ECE and across the campus, are augmented by a powerful mainframe and a Cray supercomputer. These are all

available to students, staff and faculty. In addition, virtually all ECE Department faculty have workstations and/or microcomputers in their offices.

3. *Public Works* support is barely adequate. There are frequently long delays in performing public works jobs due to lack of material or labor.

4. *Supply and equipment* ordering support is slow for orders that exceed $2,500 since these must be processed through the Supply Department. Smaller orders are placed in a much more timely manner using the department's credit card.

5. *Travel* requests are expedited through the system by the department's supply-travel clerk. However, the local Personnel Support Detachment (PSD) will often make travel reservations (faculty are forbidden from making their own airline and rental car reservations for official travel) using a sub-optimal travel itinerary to save the last nickel in fares. In addition, the local PSD usually refuses to use the major car rental companies which are located on-site at the destination airport, opting instead to make reservations for faculty using small independent rental companies who often provide poor service and who charge government rates identical to the major companies.

XII. COURSE REQUIREMENTS

A. Program modes and trends

Program mode: All courses are offered on a day basis.

Enrollment trends: There are currently 113 students enrolled in the MSEE program. A total of 71 MSEE degrees were awarded in the last calendar year. Enrollments have decreased for three of the past six years since the last visit. Enrollments peaked four years ago and declined since then. This decline is expected to stabilize now as the size of the military forces assumes a smaller steady-state condition.

B. Degree titles

Master of Science in Electrical Engineering

C. Definition of credit unit

One quarter credit hour represents one class hour or two laboratory hours per week. *For the purpose of this study, one academic year represents three quarters of study.* Each quarter is 11 weeks of class and one week of final examinations. The students attend classes or are in examination periods for 48 weeks during the calendar year.

D. Curriculum course content

The definition of one-half year of study is 24 quarter credit hours. One academic year is three quarters for the purposes of this review. (The school operates with four quarters per calendar year.)

E. Basic-level curriculum

All officers in the basic level ECE program are considered as transfer students. Only about 50% of the entering officers have a BSEE from an accredited college. The remaining students have a BS or BA in a related field. NPS provides the upper-division courses to "retread" these officers into Electrical Engineers. The courses taken depend on the background of the student. These courses are determined by consultation with the Academic Associate immediately upon enrollment.

Course requirements for the basic-level program are listed in Table XII.

Table XII is broken down into two representative programs, a program that is typical of an officer entering NPS without an accredited engineering degree (Table XII-A) and a program for an officer who received an accredited engineering degree in another engineering area (Table XII-B). Most non-BSEE officers fit the former category; relatively few fit the latter category. All international officers are in the first category of having no accredited degree.

F. Alternative modes

The MSEE degree program will be offered in a "distance learning" format begining in October 1995. The program will be delivered using advance video teleconferencing technology that permits two way audio and video interaction between the instructor and the remote class.

G. Advanced-level curriculum

Students in the advanced-level program are usually enrolled in the following curricula programs: Electronics Systems Engineering, Combat Systems Engineering, Space Systems Engineering, or

Electronic Warfare. The primary group of students is from Electronic Systems Engineering. (curriculum 590) Each MSEE candidate from these curricula meet the same MSEE requirements. The curricula differ in the option tracks and electives chosen by the officers.

The general MSEE degree requirements are as follows:

1. Credits: Complete a minimum of 52 quarter credit hours of graduate level work. Of these 52 quarter credit hours,

(a) a minimum of 36 quarter credit hours of graduate-level course work in engineering, mathematics, physical science, and/or computer science must be taken.

(b) at least 24 quarter credit hours must be in graded EC graduate courses.

(c) at least 12 quarter credit hours must be in the sequence of advanced courses (4000--4999).

(d) at least 3 quarter credit hours must be in a graduate level course in mathematics.

(e) at least 16 quarter credit hours of thesis must be taken.

2. Option: Complete all the courses required in at least one of the ECE graduate speciality options. Currently, there are six option areas: Communication Systems; Computer Systems; Electromagnetic Systems; Guidance, Navigation, and Control Systems; Power Systems; and Signal Processing Systems.

Additional information about the required courses of each option is given in Table XIII.

3. ECE Breadth: To provide breadth to a program, at least two graded graduate-level EC courses must be taken from those courses that are *outside* of the student's option.

4. Thesis: Submit an acceptable thesis (see 1(e) above).

Table XIII shows representative programs (i.e., programs that include representative preparatory courses and electives) for each of these option areas.

The following procedure is used to ensure that ABET criteria for both the basic-level and advanced-level programs are met:

The Academic Associate monitors the progress of officers through the program. When an officer completes the BSEE equivalence (if needed), the Academic Associate fills out and approves a BSEE/equivalence checklist (sample follows on pages II-31 to II-35) using the student's transcript. This approval is reviewed and signed by the Curriculum Officer and the Department Chairman. The Curriculum Officer and the ECE Department Chairman then nominate the student to the Academic Council for graduation.

When an officer completes the MSEE course requirements (usually in his last quarter), the Academic Associate fills out and approves an MSEE checklist (sample follows on pages II-36 to II-40), using the student's transcript. This approval is reviewed and signed by the Curriculum Officer and the Department Chairman. The Curriculum Office forwards the nomination for degree to the Dean of Instruction's office. The thesis is reviewed and approved by the advisor, second reader, and Department Chairman. The Dean of Research verifies that the thesis meets NPS format requirements. When an acceptable thesis is received, the Dean of Instruction forwards the nomination for award of degree to the Academic Council for approval.

The checkoff lists on pages II-31 to II-40 are given to the officers upon enrollment, and they are completed by the Academic Associate at the appropriate time.

H. Advising system

Students schedule their courses in consultation with the Academic Associate. Any changes in these programs must be approved by the Academic Associate. Substitutions, validations, or waivers for required courses must also be approved by the Department Chairman.

I. Verification of student programs of study

The Academic Associate for the primary ECE student curriculum (Electronic Systems Engineering) is Professor R. Clark Robertson. Professor Robertson advises all of the U.S. Navy students and is assisted by Professor Ronald Pieper for the U.S. non-navy students and Professor Rama Janaswamy for the international students. There are other faculty liaisons for the smaller programs, Professor Roberto Cristi for Combat Systems, Professor David Jenn for Electronic Warfare, and Professor Sherif Michael for Space Engineering.

The Academic Associate monitors the progress of officers through the program. When an officer completes the BSEE equivalence (if needed), the Academic Associate fills out and approves a BSEE/equivalence checklist (sample on pages II-31 to II-35) using the student's transcript. This approval is reviewed and signed by the Curriculum Officer, by Professor Robertson (regardless of the curriculum of origin) and the ECE Department Chairman. The Curriculum Officer and the ECE Department Chairman then nominate the student to the Academic Council for graduation. When an acceptable thesis is received, the Dean of Instruction forwards the nomination for award of degree to the Academic Council for approval.

J. Transfer credit

Transfer credits up to 12 units is allowed in the advanced level programs. The equivalence of content is assessed by the Department Chairman using a course validation form in the following manner.

(a) Previous experience with the universities and academies involved;
(b) textbooks used;
(c) personal conferences with the students.

The course validation request is signed by the Department Chairman.

K. Oral and written communication

Basic-Level Program: No specific courses in oral or written communications are offered. However, officers are expected to independently develop these skills. As military officers, the students typically enter NPS with significant presentation skills from previous duties. Students are required to submit written reports in all courses that involve laboratory exercises. Oral presentations of laboratory, project, and study papers are sometimes used in courses.

Advanced-Level Program: Each of the options has several courses that require written and/or oral reports on student projects. Additionally, all students are required to write a thesis of research activities that cover the equivalent of at least one quarter of fulltime effort. Theses are evaluated with regard to both presentation and content by the advisor, the second reader, and the Department Chairman, and must meet acceptable standards in both respects. Every thesis is presented orally at a Department seminar session devoted to thesis presentations.

L Computer experience

Basic-Level Program: All officers must have competancy to program in a high level language, such as C or ADA. Students in the Electromic Systems curriculum have a special Educational Skill Requirement (ESR) to demonstrate this competancy. Most students also enroll in EC1010, Introduction to MATLAB, since MATLAB is the *de facto* language for most assignments in the engineering courses. In addition the courses, EC2800 (Introduction to Microprocessors), EC2820 (Digital Logic Circuits), and EC3800 (Micro-processor based system design), are required of most officers.

Advanced-Level Programs: The specific use of the computer varies somewhat amongst the various option areas; however all options use the computer in one or more of the areas of simulation, laboratory, and homework assignments. The Signal Processing, Communication, and Control Systems options make extensive use of programs such as MATLAB and SIMULINK. Since modern signal processing is primarily digital, students are required to formulate and implement algorithms using the languages mentioned above. Almost without exception the courses required in these two options include computer applications in design and /or analysis problems and projects. Courses in the Computer Systems option deal extensively with computer architecture and other advanced topics such as operating systems and software engineering. The computer here is also used in digital system design using tools such as VHDL, SPICE, and others. The Power and Electronic Warfare options also use the computer primarily for analysis and simulation.

Computer usage in individual courses is addressed in the course outlines.

M. Laboratory experience

Laboratory is an integral part of the officer-student's experience at NPS. The Department's philosophy is to include a large amount of lab experience at both the basic level and the advanced level. Courses having laboratories associated with them are indicated by the laboratory credit hours assigned. Laboratory facilities are numerous and well-equipped.

Basic-Level Program: The courses in circuits (EC2100), electronics (EC2200 and EC2220), communications (EC2500), control (EC2300), digital logic circuits (EC2820), microprocessors (EC3800), and electromagnetic engineering (EC2610) all contain significant laboratory experience. In addition, EC2890, *Digital Circuit Design Laboratory* and EC2990, *Design Projects in Electrical Engineering* always involve a laboratory experience. The course instructor is in charge of the laboratory period and is supported by competent civilian and/or military technicians.

Advanced-Level Programs: A sampling of courses for each option containing a laboratory experience is given below. In some instances, the equipment used is a computer.

Communications:

Communications Engineering (EC3510)
Fiber Optic Systems (EC3550)
Communications ECCM (EC 4560)

Computer Systems:

Microprocessor-Based System Design (EC3800)
Digital Computer Design Methodology (EC 3830)
Fault-Tolerant Computing (EC4810)
VLSI Systems Design (EC4870)

Signal Processing Systems:

Speech Signal Processing (EC4410)
Image Processing and Recognition (EC4480)

Electromagnetic Systems:

Introduction to Electro-Optical Engineering (EC3210)
Microwave Engineering (EC3610)
Radar Systems (EC4610/20)
Electronic Warfare Systems (EC4680/90)

Guidance, Navigation and Control Systems:

Nonlinear Systems (EC4350)
Navigation, Missile, and Avionics Systems (EC4330/40)

Power Systems:

Electrical Machine Theory (EC3130)
Solid State Power Conversion (EC3150)
Advanced Electrical Machinery Systems (EC4130)
Advanced Solid State Power Conversion (EC4150)

Safety: Laboratory safety procedures are included in the laboratory exercises and instructions provided to the students. The Laboratory technician staff is thoroughly indoctrinated in electrical shock and radiation hazard. Several of the lab staff are CPR-qualified with annual updates provided by the NPS Safety Office.

Electrical safety: Students receive a safety orientation in the first laboratory of the electric circuits course. The lab technician presents an overview of the problems of electrical safety and precautions. Individual laboratory instruction sheets point to any unusual safety problems such as high voltage.

Electromagnetic radiation safety: Students enrolled in the microwave courses and in the radar courses receive safety instructions from the laboratory technician in the first lab session. The electrical distribution is described, as are emergency shutdown procedures. Microwave exposure limits are discussed and placed in the context of waveguide and antenna field levels. Safety problems are noted and precautions are described. The individual laboratory sheets contain information related to any unusual safety conditions.

Laser safety: Laser safety is included in the demonstrations performed before allowing the students to perform the lab exercises. Specific safety issues pertinent to the laser in use, including the minimum safe viewing distance, are included in the Lab exercise instructions. Protective eyewear is available for all exercises. Most student exercises are performed with lasers with a minimum safe viewing distance of 2 inches or less. More powerful lasers are demonstrated by the instructor; no student exercises are performed using them.

Hazardous materials: Hazardous materials sheets are given to students using hazardous materials as part of a laboratory exercise (e.g., epoxies). The technician staff is well-indoctrinated into the ordering, storage, and handling of hazardous materials, because of strict regulation imposed in government workplaces.

N. **Engineering design experience**

Basic level: The engineering design experience is based primarily on the following courses:

EC3800 (3-2) Microprocessor Based System Design (65% design)
EC2220 (2-4) Applied Electronics (100% design)
EC 2990 (2-4) Design Project in Electrical Engineering (100% design)

All students receiving the equivalence of a BSEE degree take EC3800 or EC2220. Most take both. The EC2990 project design course consists entirely of design and is intended to increase the exposure of students to the design experience.

Advanced level: The primary design effort is in the thesis, although most advanced courses have design content embedded in them. The thesis is an open-ended investigation into a topic of mutual interest to the student and the advisor. The required integration of effort, individual attention, reporting of results, and other hallmarks of the design requirement are all contained in this effort. The thesis is at least 16 quarter credit hours. The Department estimates the design content as 12 credits and the other components as 4 credits.

O. **Course/section size**

See Table XIV, Course/Section Size Summary.

P. **Humanities and social sciences requirements.**

A baccalaureate degree is required for admission into the program, and the ABET requirement for humanities and social sciences is generally satisfied by this degree. In the event that the baccalaureate degree is not sufficient to satisfy the humanities and social sciences requirement, the deficit must be made up either by taking suitable courses at a local junior college or by taking appropriate courses offered at NPS such as NS3300, *History and Cultures of the Middle East.*

Q. **Inclusion of probability and statistics**

Probability and statistics are an essential part of the program.

Basic level: Students must take, or have the equivalent of EC2010, *Probabilistic Analysis of Signals and Systems*. This provides necessary background not only for the analysis of random signals, but also for the analysis of networks encountered in communications and computer systems.

Advanced level: Below is a listing of the option areas and the graduate level courses involving probability and/or statistics which students in the option take. Detailed content of these courses can be found in the pages of course descriptions.

Communications:

EC3500, Analysis of Random Signals
EC3510, Communications Engineering
EC4550, Digital Communications
EC4570, Signal Detection and Estimation
EC4580, Coding and Information Theory

Computer Systems:

EC3850, Computer Communication Methods

EC4810, Fault Tolerant Computing
EC4850, High Speed Networking

Signal Processing Systems:

EC3410, Discrete-Time Random Signals
EC3420, Statistical Digital Signal Processing
EC4410, Speech Signal Processing
EC4420, Modern Spectral Analysis
EC4470, Adaptive Signal Processing

Electromagnetic Systems:

EC4610/20, Radar Systems
EC4680/90, Radar Electronic Warfare Techniques and Systems

Guidance, Navigation, and Control Systems:

EC3310, Optimal Estimation: Sensor and Data Association
EC4320, Design of Robust Control Systems
EC4360, Adaptive Control Systems

Power Systems:

EC3150, Solid State Power Conversion
EC4150, Advanced Solid State Power Conversion

R. ABET program criteria requirements

The curriculum requirements for an Electrical Engineering program include that:

(a) The curriculum must provide depth and breadth...

Basic level: The degree requirements for the BSEE equivalent ensure the full mixture of humanities and engineering courses are taken. The requirement for breadth and depth are met by listing the equivalent NPS course sequences on the BSEE equivalence checklist. These sequences (or their equivalent) ensure depth. The breadth requirements is ensured by the variety of sequences included on that checklist.

Advanced level: The depth requirement is met by the degree requirement for specialization in an optional area. The breadth requirement is met by requiring courses in math, courses in other option area.

(b) Mathematics: Additional work is required in one or more of the subjects of...

Basic level: All students are required to take probability and statistics (EC2010) or equivalent. All BSEE equivalence students take a math course in linear algebra and vector and complex variable analysis (a single course on both topics).

Advanced level: A graduate level math course is required of all MSEE students.

(c.) Engineering design: Advanced courses that emphasize design must have a size and structure that provide individual attention to each student...

Basic level: The primary courses that meet the basic level design requirement are EC3800 (Microprocessor Based Systems Design -- 65% design) and EC2220 (Applied Electronics -- 100% design). These courses use small design teams of up to three students to perform the projects. The faculty members instructing the course are available to the students during the scheduled lab hours and outside of the class and lab. Additionally, electronic technicians are available to guide students during working hours.

The design project courses (EC2890 and EC2990) involve a small team of up to three students working individually with a Professor on their project. Other courses with intensive design content (EC2220 and EC3800) are presented to small sections. The instructor is required to be available to the students during the scheduled lab hours and outside of scheduled class and lab hours.

Advanced level: The primary component of the advanced level design experience, the thesis, is always a one-on-one relationship between the thesis student and the thesis advisor.

(c.) Engineering design (continued): As a minimum a course that satisfies this requirement must have a course that is more than half engineering design and must be in the junior or senior year of the program. It... must have as a prerequisite at least one course in the discipline.

All courses in the NPS MSEE program are at the upper division or graduate level. Each of the design courses described above has at least one course as a prerequisite.

Basic level: The primary design courses have the following content.

Course	Design Fraction
EC2220	100%
EC2990	100%
EC3800	65%

Advanced level: The primary design experience is the thesis which has a conservatively estimated design fraction of 75% (see Section XII N).

(d.) Computer use. Appropriate use of computers must be integrated throughout the program. Acceptable use will include... (1) Programming in high level languages..., (2) use of software packages..., (3) documentation of programs, (4) use of systems software..., and (5) simulation of engineering problems.

Computers are thoroughly integrated into the students' work at NPS. Computer resources are readily available without any charge at the Computer Center and ECE Department. Examples include public workstations, PCs installed in various laboratories, and personally owned PCs. A significant fraction of the courses offered, ranging from elementary to advanced courses, use computers in laboratory exercises, homework assignments, and projects. The individual course descriptions identify these courses and the computer usage.

TABLE XII-A
COURSE REQUIREMENTS OF CURRICULUM
BASIC LEVEL PROGRAM

Typical program for a student entering
without an accredited Engineering degree

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	Calculus (Entrance requirement)	12				
	MA1043 Intensive Matrix Algebra	2				
	MA2051 Vector Analysis	3				
	MA2121 Differential Equations	4				
	MA3046 Matrix Theory & Computational Linear Algegra	4.5				
	Physics (entrance requirement)	12				
	CS2971 Intro. to Object-Oriented Programming with C++					4
	EC 2100 Intro. to Circuit Analysis		4	1		
	EC 2820 Digital Logic Circuits		2	2		
	Basic Science 1/4 year Chemistry Other basic science courses	 6 6				
	EC 2200 Intro. to Electronics Engineering		2.5	2		
	EC 3100 Adv. Circuit Analysis		3	1		
	EC 3200 Adv. Electronics Engineering		2	2		
	Non-EE Engineering Science courses (Courses in statics, dynamics, thermodynamics, fluid mechanics, mechanics of solids, etc.)		8			
	EC 2600 Intro. to Fields & Waves		4			
	EC 2610 Electromagnetic Engineering		2	1.5		
	EC 2400 Discrete Signals and Systems		2.5	1		
	EC 2410 Fourier Analysis of Signals & Systems		2.5	1		
	EC 2320 Linear Systems		2.5	1		
	EC 2800 Intro. to Microprocessors		2	2		
	EC 2010 Prob. Analysis of Signals & Systems		3	0.5		
	EC 2300 Control Systems		2	2		
	continued on next page					

*Due to officers being able to enter the program in any quarter and multiple course offerings during a year, it is not possible to describe the year and quarter for a course.

TABLE XII-A (continued)
COURSE REQUIREMENTS OF CURRICULUM
BASIC LEVEL PROGRAM

Typical program for a student entering without an accredited Engineering degree

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
	Continued from previous page.					
*	EC 2500 Communications Theory		3	1		
	EC 2220 Design of Electronic Circuits			4		
	EC 3800 Microprocessor-Based System Design		1.5	2.5		
	Engineering Science electives (courses in energy conversion, internal combustion engines, naval machinery, rotating machinery, etc.		4			
	Engineering design electives EC 2990 Design Projects in EE *or* other design courses, such as machine design, etc.			4		
	Humanities (Entrance requirement)				24	
	Other courses (Additional courses in math, basic sciences, enginr. science, enginr. design, and humanities to complete the program)					23.5
TOTALS–BASIC PROGRAM		49.5	50.5	28.5	24	27.5
OVERALL TOTAL FOR DEGREE		180 quarter credit hrs				
PERCENT OF TOTAL		27%	28%	16%	13%	16%
Must satisfy one set of conditions	Minimum semester credit hours	32	32	16	16	
	Minimum quarter credit hours	48	48	24	24	
	Minimum percentage	25%	25%	12.5%	12.5%	

*Due to officers being able to enter the program in any quarter and multiple course offerings during a year, it is not possible to describe the year and quarter for a course.

TABLE XII-B
COURSE REQUIREMENTS OF CURRICULUM
BASIC LEVEL PROGRAM

Typical program of an entering student
with accredited non-EE Engineering degree

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	Calculus (Entrance requirement)	12				
	Engineering mathematics (Entrance requirements)	12				
	Chemistry and Physics (entrance requirement)	24				
	Computer programming (entrance requirement)					4
	Circuit analysis (entrance requirement)		4			
	EC 2820 Digital Logic Circuits		2	2		
	EC 2200 Intro. to Electronics Engineering		2.5	2		
	EC 3100 Adv. Circuit Analysis		3	1		
	EC 3200 Adv. Electronics Engineering		2	2		
	Non-EE Engineering Science courses (Courses in statics, dynamics, thermodynamics, fluid mechanics, mechanics of solids, etc.)		12	6		
	EC 2600 Intro. to fields & waves		4			
	EC 2610 Electromagnetic Engineering		2	1.5		
	EC 2400 Discrete Signals and Systems		2.5	1		
	EC 2410 Fourier Analysis of Signals & Systems		2.5	1		
	EC 2320 Linear Systems		2.5	1		
	EC 2800 Intro. to Microprocessors		2	2		
	EC 2010 Prob. Analysis of Signals & Systems		3	0.5		
	EC 2300 Control systems		2	2		
	continued on next page					

*Due to officers being able to enter the program in any quarter and multiple course offerings during a year, it is not possible to describe the year and quarter for a course.

TABLE XII-B (continued)
COURSE REQUIREMENTS OF CURRICULUM
BASIC LEVEL PROGRAM

Typical program of an entering student
with accredited non-EE Engineering degree

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
	Continued from previous page.					
*	EC 2500 Communications Theory		3	1		
	EC 2220 Design of Electronic Circuits			4		
	EC 3800 Microprocessor Based System Design		1.5	2.5		
	Humanities (Entrance requirement)				24	
	Other courses (Additional courses in math, basic sciences, enginr. science, enginr. design, and humanities to complete the program)					24
TOTALS–BASIC PROGRAM		48	50.5	29.5	24	28
OVERALL TOTAL FOR DEGREE		180 quarter credit hrs				
PERCENT OF TOTAL**		27%	28%	16%	13%	16%
Must satisfy one set of conditions	Minimum semester credit hours	32	32	16	16	
	Minimum quarter credit hours	48	48	24	24	
	Minimum percentage	25%	25%	12.5%	12.5%	

*Due to officers being able to enter the program in any quarter and multiple course offerings during a year, it is not possible to describe the year and quarter for a course.

** These percentages total more than 100% because of the large number of transfer credits for these officers.

TABLE XIII-A
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Communications Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	EC 3500 Analysis of Random Signals		4	0		
	EC 3510 Communications Engineering		2.5	1		
	EC 4550 Digital Communications		3	1		
	At least one of the following totalling at least: EC 3550 Fiber Optic Systems (3-1) EC 4500 Adv Topics in Communications (3-0) EC 4570 Signal Detection & Estimation (4-0)		3	1		
	At least one of the following totalling at least: EC 4560 Communications ECM (3-2) EC 4580 Coding & Information Theory (4-0)		2	1		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3210 Intro. to Electro-Optic Engineering		2.5	1		
	EC 3400 Digital Signal Processing		2.5	1		
	EC 3600 Electromagnetic Radiation, Scattering, & Propagation		2	2		
	EC 3610 Microwave Engineering		3	1		
	EC 4410 Speech Signal Processing		2.5	1		
	EC 4590 Communications Satellite Eng.		2	1		
TOTALS - ADVANCED LEVEL		3	33	23		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIII-B
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Computer Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	*Any three of the following, totalling at least:* EC 3800 Microprocessing Based System Design (3-2) EC 3820 Computer Systems (3-1) EC 3830 Digital Computer Design Methodology (3-2) EC 3840 Intro. to Computer Architecture (3-2)		5.5	3		
	At least two of the following totalling at least: EC 4800 Adv. Topics in Computer Eng (3-0) EC 4810 Fault Tolerant Computing (3-2) EC 4820 Computer Architectures (3-1) EC 4830 Digital Computer Design (3-1) EC 4850 Computer Comm. methods (3-0) EC 4870 VLSI Systems Design (3-2)		4	1		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3210 Intro. to Electro-Optical Engineering		3	1		
	EC 3400 Digital Signal Processing		2.5	1		
	EC 3310 Linear Optimal Estimation & Control		2.5	1		
	EC 4210 Electro-Optic Systems Engineering		2.5	0.5		
	EC 4460 Systems Engineering		1	2		
	EC 4100 Advanced Network Theory		2.5	1		
TOTALS - ADVANCED LEVEL		3	27.5	22.5		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIII-C
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Electromagnetics Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	EC 3600 Electromagnetic Radiation, Scattering, & Propagation		2	2		
	At least one of the following totalling at least: EC 3210 Intro. to Electro-Optical Eng (3-1) EC 3610 Microwave Circuits (3-2) EC 3630 Radiowave Propagation (3-0) EC 3650 Computational EM Modeling Techniques (4-1)		3	1		
	At least two of the following totalling at least: EC 4210 Electro-Optic Systems Eng. (3-0) EC 4600 Advanced Electromagnetics (3-0) EC 4610/20 Radar Systems (3-2) EC 4630 Radar Cross Section Prediction & Reduction (3-0) EC 4660 EM Environmental Effects on Comm System Performance (3-2) EC 4680 Electronic Warfare Techniques & Systems (3-3) EC 4690 Principles of Electronic Warfare (3-2)		5	2		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3400 Digital Signal Processing		2.5	1		
	EC 3670 Principles of Radar Systems		4	1		
	EC 4010 Principles of Systems Engineering		1	3		
	EC 4570 Signal Detection & Estimation		3.5	0.5		
	EC 4330/40 Navigation, Missile & Avionics Systems		3	1		
	EC 4450 Sonar Systems Engineering		4	0.5		
TOTALS - ADVANCED LEVEL		3	28	23		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIII-D
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Guidance, Navigation, & Control Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	EC 3310 Optimal Estimation & Data Assoc.		2	1.5		
	EC 3410 Discrete Time Random Processes		4	0		
	EC 4320 Design of Linear Control Systems		2	2		
	EC 4350 Nonlinear Control Systems		2	2		
	At least one of the following totalling at least: EC 4330/40 Navigation, Missile & Avionics Systems (4-0) EC 4360 Adaptive Control (3-1) EC 4370 Mathematical Models & Simulation for Control Systems (4-0)		2	2		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3400 Digital Signal Processing		2.5	1		
	EC 3420 Modern Methods of Digital Signal Processing		2.5	1		
	EC 3600 Electromagnetic Radiation, Scattering, & Propagation		2	2		
	EC 3820 Computer Systems		2.5	1		
	EC 4010 Principles of Systems Engineering		1	3		
	EC 4570 Signal Detection & Estimation		3.5	0.5		
	EC 4870 VLSI Systems Design		1	3		
TOTALS - ADVANCED LEVEL		3	31	31		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIII-E
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Power Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci	Engr Design	Hum & Soc Sci	Other
*	EC 3130 Electrical Machinery Theory		3.5	1.5		
	EC 3150 Solid State Power Conversion		2.5	1		
	EC 4130 Adv. Electrical Machinery Theory		3	2		
	EC 4150 Adv. Solid State Power Conversion		2.5	2		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3100 Advanced Circuit Analysis		3	1		
	EC 3200 Advanced Electronic Engineering		2	2		
	EC 3600 EM Radiation, Scattering, & Propagation		2	2		
	EC 4010 Principles of Systems Engineering		1	3		
	EC 4220 Intro. to Analog VLSI		1.5	2		
TOTALS - ADVANCED LEVEL		3	25	28.5		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIII-F
COURSE REQUIREMENTS OF CURRICULUM
ADVANCED LEVEL PROGRAM
Signal Processing Systems Option

Year Quarter	Course (Department, number, title)	Category (Credit hours) Math & Basic sci	Engr Sci (ES)	Engr Design (ED)	Hum & Soc Sci	Other
*	EC 3400 Digital Signal Processing		2.5	1		
	EC 3410 Discrete Time Random Signals		4	0		
	EC 3420 Statistical Digital Signal Processing		2.5	1		
	At least two of the following, totalling at least: EC 4410 Speech Signal Processing (3-1) EC 4420 Modern Spectral Analysis (3-1) EC 4450 Sonar Systems Engineering (4-1) EC 4470 Adaptive Signal Processing (3-1) EC 4480 Image Proc. & Recognition (3-2) EC 4490 Ocean Acoustic Tomography (3-0)		3.5	3		
	MA 3xxx (One graduate math course)	3				
	EC 0810 Thesis**		4	12		
Courses taken above are required courses. Course below are typical courses taken to satisfy degree requirements, preparation for thesis, and individual interests.						
	EC 3310 Optimal Estimation & Data Association		2	1.5		
	EC 3600 Electromagnetic Radiation, Scattering, & Propagation		2	2		
	EC 3850 Computer Communications Methods		2.5	1		
	EC 4010 Principles of Systems Engineering		1	3		
	EC 4570 Signal Detection & Estimation		3.5	0.5		
	EC 4360 System Identification		1.5	2		
TOTALS - ADVANCED LEVEL		3	29	27		

* Due to variability in student entrance quarter and course scheduling, it is not possible to specify the year and quarter of the courses.

** MSEE degree requirements are 36 course credits plus thesis (16 credits) for total of 52 credits.

TABLE XIV
Course/Section Size Summary

Course No.	Title	No. of Sections Offered in Current Year	Avg. Section Enrollment	Type of Class			
				Lecture	Lab	Recit.	Other (specify)
EC0819	Thesis research	4	—				Not a class
EC0950	Seminar	4	120				Seminar
EC1010	Introduction to MATLAB	4	45	50	50		
EC2010	Probabilistic Analysis of Sig. & Sys.	2	26	75	25		
EC2100/2170	Circuit Analysis	4	12	67%	33%	0%	
EC2200	Introduction to Electronics Engineering	2	15	50%	50%	0%	
EC2220	Applied Electronics	2	14	33%	67%	0%	
EC2270	Basic Electronics & Electrical Machines	3	9	67%	33%		
EC2300	Control Systems	3	12	60%	40%	0%	
EC2320	Linear systems	2	7	75%	25%	0%	
EC2400	Discrete Systems	5	19	75%	25%	0%	
EC2410	Analysis of Signals & Systems	4	20	75%	25%	0%	
EC2450	Accelerated Review of Linear Systems	0	–	100%	0%	0%	
EC2500	Communications Systems	4	16	60%	40%	0%	
EC2600	Electromagnetic Fields & Waves	2	21	100%	0%	0%	
EC2610	Electromagnetic Engineering	2	15	75%	25%	0%	
EC2650	Accelerated Review of Electromagnetics	0	—	67%	33%	0%	
EC2800	Introduction to Microprocessors	2	17	60%	40%	0%	
EC2820	Digital Logic Circuits	3	19	60%	40%	0%	
EC2890	Digital Circuit Design Laboratory	0	—	0%	100%		
EC2990	Design Projects in Electrical Eng.	4	1	0%	100%		

TABLE XIV (continued)
Course/Section Size Summary

Course No.	Title	No. of Sections Offered in Current Year	Avg. Section Enrollment	Type of Class			
				Lecture	Lab	Recit.	Other (specify)
EC3100	Advanced Circuit Analysis	1	20	60%	40%		
EC3130	Electrical Machine Theory	1	11	67%	33%		
EC3150	Solid State Power Conversion	1	10	60%	40%		
EC3200	Advanced Electronics Engineering	1	15	60%	40%		
EC3210	Intro. to Electro-Optic Engineering	1	15	75%	25%	0%	
EC3310	Optimal Est: Sensor & Data Assoc.	1	5	75%	25%	0%	
EC3320	Optimal Control Systems						New course
EC3400	Digital Signal Processing	2	14	75%	25%	0%	
EC3410	Discrete Time Random Signals	2	9	100%	0%	0%	
EC3420	Statistical Digital Signal Processing	1	11	75%	25%	0%	
EC3450	Fundamentals of Ocean Acoustics	1	6	100%	0%	0%	
EC3500	Analysis of Random Signals	2	14	100%	0%	0%	
EC3510	Communications Engineering	2	12	75%	25%	0%	
EC3550	Fiber Optics Systems	2	29	75%	25%	0%	
EC3600	Electromagnetic Radiation, Scattering & Propagation	2	17	60%	40%	0%	
EC3610	Microwave Engineering	1	8	60%	40%	0%	
EC3630	Radiowave Propagation	1	7	100%	0%		
EC3650	Computational Electromagnetics Modeling Techniques	1	6	80%	20%	0%	
EC3670	Principles of Radar Systems	1	17	67%	33%	0%	
EC3800	Microprocessor Based System Design	2	19	75%	25%	0%	
EC3820	Computer Systems	2	14	75%	25%	0%	
EC3830	Digital Computer Design Methodology	1	28	60%	40%	0%	
EC3840	Introduction to Computer Architecture	1	23	60%	40%		
EC3850	Computer Communication Methods	2	22	100%	0%		
EC3910	Special Topics in Electrical Engineering	1	11	varies	varies	0%	

TABLE XIV (continued)
Course/Section Size Summary

Course No.	Title	No. of Sections Offered in Current Year	Avg. Section Enrollment	Type of Class			
				Lecture	Lab	Recit.	Other (specify)
EC4000	Future Engineering Practice	2	61	100%	0%		
EC4010	Principles of Systems Engineering	1	8	75%	25%		
EC4130	Advanced Electrical Machinery Systems	1	10	67%	33%		
EC4150	Advanced Solid State Power Conversion	1	7	80%	20%		
EC4210	Electo-Optic Systems Engineering	1	11	100%	0%	0%	
EC4220	Introduction to Analog VLSI	1	8	75%	25%		
EC4300	Adv. Topics in Modern Control Sys.	1	16	100%	0%	0%	
EC4320	Design of Robust Control Systems	1	12	60%	40%	0%	
EC4330/4340	Navigation, Missile, & Avionics (classified/unclassified)	1	6	50%	50%	0%	
EC4350	Nonlinear Control Systems	1	10	60%	40%	0%	
EC4360	Adaptive Control Systems	1	2	75%	25%		
EC4400	Advanced Topics in Signal Processing	1	9	100%	0%		
EC4410	Speech Signal Processing	1	12	75%	25%		
EC4420	Modern Spectral Analysis	1	8	75%	25%		
EC4450	Sonar Systems Engineering	2	9	80%	20%	0%	
EC4460	Artificial Neural Networks						New course
EC4470	Adaptive Signal Processing	1	13	75%	25%		
EC4480	Image Processing & Recognition	1	5	60%	40%		
EC4490	Ocean Acoustic Tomography	1	6	100%	0%		
EC4500	Advanced Topics in Communications	1	9	100%	0%		
EC4550	Digital Communications	2	12	100%	0%	0%	
EC4560	Communications ECCM	1	13	60%	40%	0%	
EC4570	Signal Detection and Estimation	1	16	100%	0%	0%	
EC4580	Coding & Information Theory	2	10	100%	0%	0%	
EC4590	Comm. Satellite Sys. Eng.	1	12	100%	0%	0%	

TABLE XIV (continued)
Course/Section Size Summary

Course No.	Title	No. of Sections Offered in Current Year	Avg. Section Enrollment	Type of Class			
				Lecture	Lab	Recit.	Other (specify)
EC4600	Advanced Electromagnetics	1	5	100%	0%	0%	
EC4610/4620	Radar Systems (classified/unclassified)	2	5	60%	40%	0%	
EC4630	Radar Cross Section Prediction & Reduction	1	8	100%	0%		
EC4660	Electromagnetic Environmental Effects on Communication Systems Performance	0	—	60%	40%	0%	
EC4670/4680	Electronic Warfare (class/unclass)	1	18	50%	50%	0%	
EC4690	Radar Electronic Warfare Techniques & Systems (unclassified)	1	8	50%	50%	0%	
EC4800	Advanced Topics in Computer Architecture	1	15	100%	0%		
EC4810	Fault Tolerant Computing	1	15	60%	40%		
EC4820	Advanced Computer Architecture	1	8	75%	25%	0%	
EC4830	Digital Computer Design	1	22	75%	25%	0%	
EC4850	High Speed Networking	0	—	60%	40%	0%	
EC4870	VLSI Systems Design	1	18	60%	40%	0%	
EC4900	Special Topics in Electrical Engineering	4	13	0%	0%		100% self study
EC4910,20...	Adv. Topics in Electrical Eng.	6	10	varies	varies		

NAVAL POSTGRADUATE SCHOOL
Department of Electrical and Computer Engineering

Checklist for BSEE Degree Equivalence

Officer name: ______________________________

Month/year enrolled: ________________________

Institutions attended	Dates	Degree

I certify that the information contained on this form is correct.

____
Officer–student

We certify that this student has met the minimum requirements for a BSEE equivalence and is therefore admitted into the advanced–level program leading to the MSEE degree.

BSEE satisfied by BSEE degree/BSEE equivalence Date:____________________

____
Academic Associate

____
ECE Chairman

____
Curriculum Officer

Detailed BSEE Checklist

I. Required courses (Please fill in the course number):

1. A course in calculus-based Physics: ____________
2. A course in Chemistry: ____________
3. A second course in either Physics or Chemistry that built on the course in part 1 or 2: ________

II. Mathematics (minimum of 24 quarter credit-hours or 16 semester credit-hours):

	NPS Course	Other University Course number	Qtr Credits
Matrix Algebra	MA 1042 or MA 1043	________	2
Calculus (entrance requirement)	MA 1117 & MA 1118	________	12
Logic, Sets and Functions	MA 2025	________	4.5
Vector Analysis	MA 2049 or MA 2051	________	3
Differential Equations	MA 2121	________	4
Probability	OS 2102	________	4.5
Partial Differential Equations	MA 3132	________	4
Numerical Analysis	MA 3232	________	4.5
Discrete Mathematics & Automata Theory	MA 3026	________	5
________	________	________	________
________	________	________	________
		TOTAL	________

III. Basic Sciences: (minimum of 24 quarter credit-hours or 16 semester credit-hours):

	NPS Course	Other University Course number	Qtr Credits
Physics (entrance requirement)	PH 1121 & PH 1322	________	10
Chemistry	________	________	6
Astronomy	________	________	________
Biology	________	________	________
Geology	________	________	________
Meteorology	________	________	________
Oceanography	________	________	________
________	________	________	________
		TOTAL	________

Minor Revisions: 13 September 1994

IV. Engineering Sciences: (minimum of 48 quarter credit–hours or 32 semester credit–hours of which at least 36 quarter credit-hours must be electrical engineering or equivalent):

	NPS Course	Other University Course number	Qtr Credits
a. Circuits and Electronics			
*Introduction to Circuit Analysis	EC 2100	____________	4
*Advanced Circuit Analysis	EC 3100	____________	3
*Introduction to Electronics Engineering	EC 2200	____________	2.5
*Advanced Electronics Engineering	EC 3200	____________	2
b. Computer Engineering			
*Intro to Microprocessors	EC 2800	____________	2
*Digital Logic Circuits	EC 2820	____________	2
*Microprocessor-based System Design	EC 3800	____________	1.5
c. Systems, Communications, & Control			
*Control Theory	EC 2300	____________	2
*Discrete Signals & Systems	EC 2400	____________	3
Fourier Analysis of Signals & Systems	EC 2410	____________	3
*Linear Systems	EC 2320	____________	2
*Communications Systems	EC 2500	____________	3
*Prob. Analysis of Signals & Systems	EC 2010	____________	3
d. Electromagnetics			
Electromagnetic Fields and Waves	EC 2600	____________	4
*Electromagnetic Engineering	EC 2610	____________	2
e. Other Engineering Science Courses (at least one *non-EE course is required).*			
Mechanics of Solids	ME 2601	____________	4
Thermodynamics	ME 2101	____________	4.5
Fluid Mechanics	ME 2201	____________	4
____________________	________	____________	______
____________________	________	____________	______
____________________	________	____________	______
		TOTAL	______

* Indicates a course whose credits are divided between Engineering Science and Engineering Design.

Minor Revisions: 16 March 1995

V. Engineering Design: (minimum of 24 quarter credit-hours or 16 semester credit-hours of which at least 18 quarter credit-hours must be electrical engineering or equivalent):

	NPS Course	Other University Course number	Qtr Credits
a. An integrated design experience at an advanced level (Required)			
Applied Electronics	EC 2220	______________	4
* Microprocessor-based System Design	EC 3800	______________	2.5
Design Project in ECE	EC 2990	______________	4
b. Circuits & Electronics			
* Introduction to Circuit Analysis	EC 2100	______________	1
* Advanced Circuit Analysis	EC 3100	______________	1
* Introduction to Electronics Engineering	EC 2200	______________	2
* Advanced Electronics Engineering	EC 3200	______________	2
c. Computer Engineering			
* Intro to Microprocessors	EC 2800	______________	2
* Digital Logic Circuits	EC 2820	______________	2
d. Systems, Communications, & Control			
* Control Theory	EC 2300	______________	2
* Discrete Signals & Systems	EC 2400	______________	1
* Linear Systems	EC 2320	______________	1
* Communications Systems	EC 2500	______________	1
*Prob. Analysis of Signals & Systems	EC 2010	______________	0.5
e. Electromagnetics			
* Transmission Lines	EC 2610	______________	1.5
f. Other Engineering Design Courses			
______________________________	________	______________	______
______________________________	________	______________	______
______________________________	________	______________	______
		TOTAL	______

* Indicates a course whose credits are divided between Engineering Science and Engineering Design.

Minor Revisions: 16 March 1995

VI. Humanities and Social Sciences (minimum of 24 quarter credit–hours or 16 semester credit–hours):

Subjects	Qtr Credits
________________________________	________
________________________________	________
________________________________	________
________________________________	________
________________________________	________
________________________________	________
________________________________	________
TOTAL	________

File: handbook.ltx
Requirements set: 1 March 1989
Minor revisions: 13 September 1994
Format updated: 11 January 1993

NAVAL POSTGRADUATE SCHOOL
Department of Electrical and Computer Engineering

Checklist for MSEE Degree

Officer name: ______________________________

Month/year enrolled: ________________________

I certify that the information contained on this form is correct.

____

Officer–student

We certify that this student has met the minimum requirements for the MSEE degree.

Signatures:

______________________________ ______________________________

Academic Associate ECE Assoc. Chairman for Students

______________________________ ______________________________

Curriculum Officer ECE Chairman

____

Date

Effective date: October 1994

1. BSEE Degree/Equivalence requirement satisfied by (fill in one):
   - BSEE degree from ______________________ Month/year:____________
   - BSEE equivalence from NPS. Date:____________
2. Thesis credits (16 minimum): ______

   Title: ____

   Advisor: ____

   Presentation date: _________ Where? (ECE Seminar?) __________________

The remaining requirements must be met exclusive of thesis requirements.

3. Required courses in one option (circle the courses taken in your option):

Communications Systems

EC 3500	Analysis of Random Signals	(4–0)
EC 3510	Communications Engineering	(3–1)
EC 4550	Digital Communications	(4–0)

At least one of:

EC 3550	Fiber Optic Systems	(3–1)
EC 4500	Advanced Topics in Communications	(3–0)
EC 4570	Decision and Estimation Theory	(4–0)

At least one of:

EC 4560	Communications ECCM	(3–2)
EC 4580	Coding and Information Theory	(4–0)

Computer Systems

Any three of:

EC 3800	Microprocessor–based System Design	(3–2)
EC 3820	Computer Systems	(3–1)
EC 3830	Digital Design Methodology	(3–2)
EC 3840	Introduction to Computer Architectures	(3–1)

At least two of:

EC 4800	Advanced Topics	(3–0)
EC 4810	Fault Tolerant Computing	(3–2)
EC 4820	Advanced Computer Architectures	(3–1)
EC 4830	Digital Computer Design	(3–1)
EC 4870	VLSI Systems Design	(3–2)

Effective date: October 1994

Electromagnetic Systems

EC 3600	Electromagnetic Radiation, Scattering, and Propagation	(3–2)

At least one of:

EC 3210	Introduction to Electro–optical Engineering	(3–1)
EC 3610	Microwave Engineering	(3–2)
EC 3630	Radiowave Propagation	(3–0)
EC 3650	Computational Electromagnetic Modeling Techniques	(4–1)

At least two of:

EC 4210	Electro–optic Systems Engineering	(3–0)
EC 4600	Advanced Electromagnetics	(3–0)
EC 4610	Radar Systems	(3–2)
or EC 4620		
EC 4630	Radar Cross Section Prediction and Reduction	(3–0)
EC 4660	Electromagnetic Environmental Effects on Communication System Performance	(3–2)
EC 4680	Electronic Warfare Techniques and Systems	(3–3)
or EC 4690	Principles of Electronic Warfare	(3–2)

Guidance, Control, and Navigation Systems

EC 3410	Discrete-Time Random Signals	(4–0)
or EC 3500	Analysis of Random Signals	(4–0)
EC 3310	Optimal Estimation and Control	(3–1)
EC 4320	Design of Linear Control Systems	(4–0)
EC 4350	Nonlinear Systems	(3–1)

At least one of:

EC 4330	Navigation, Missile, and Avionics Systems	(2–2)
or 4340		
EC 4360	System Modeling and Identification	(3–1)
EC 4370	Modeling and Simulation for Control Systems	(4–0)

Power Systems

EC 3130	Electrical Machinery Theory	(4–2)
EC 3150	Solid State Power Conversion	(3–2)
EC 4130	Advanced Electrical Machinery Systems	(4–2)
EC 4150	Advanced Solid State Power Conversion	(4–1)

Effective date: October 1994
Minor Revisions: 20 May 1994

Signal Processing Systems

EC 3400	Digital Signal Processing	(3–1)
EC 3410	Discrete-Time Random Signals	(4–0)
EC 3420	Statistical Digital Signal Processing	(3–1)

At least two of:

EC 4410	Speech Signal Processing	(3–1)
EC 4420	Modern Spectral Analysis	(3–1)
EC 4450	Sonar Systems Engineering	(4–1)
EC 4470	Adaptive Signal Processing	(3–1)
EC 4480	Image Processing and Recognition	(3–2)
EC 4490	Ocean Acoustic Tomography	(3–0)

4. At least two graded EC courses outside of the option:

____________________ ____________________

5. Course credit requirements (list all graduate courses taken):

3000–level courses	Credits	4000–level courses	Credits

Total graduate credits in approved engineering, mathematics, physical science, and/or computer science (36 minimum at 3xxx and 4xxx–level): ______

Total credits in ECE 3xxx and 4xxx courses (24 graded credits): ______

Total credits at 4000 level (12 minimum, 4 courses minimum, at least three of which must be graded): ______

6. At least 3 credits in a graduate course in mathematics:

MA __________________ Credits: ______

Effective date: October 1994
Minor revisions: 19 May 1994

Elective Courses (courses not appearing in any option)

EC 3100 Advanced Circuit Analysis (3–2)
EC 3200 Advanced Electronics Engineering (3–2)
EC 3450 Fundamentals of Ocean Acoustics (4–0)
EC 3850 Computer Communications Methods (3–0)
EC 4000 Future Engineering Practice (3–0)
EC 4010 Defense Systems Engineering (3–1)
EC 4220 Introduction to Analog VLSI (3–1)
EC 4300 Advanced Topics in Modern Control Systems (3–0)
EC 4400 Advanced Topics in Signal processing (3–0)
EC 4590 Communications Satellite Systems Engineering (3–1)

CS 3310 Artificial Intelligence (4–0)
CS 4112 Operating Systems (3–2)
CS 4202 Computer Graphics (3–2)
CS 4311 Expert Systems (3–2)
CS 4313 Advanced Robotic Systems (4–0)
CS 4314 Symbolic Computing (3–2)
CS 4451 Design and Analysis of Multiple–processor, Real–time Computers (4–1)
CS 4500 Software Engineering (3–1)
CS 4550 Computer Networks II (4–0)

MA 3046 Matrix Theory and Computational Linear Algebra (4–1)
MA 3132 Partial Differential Equations and Integral Transforms (4–0)
MA 3232 Numerical Analysis (4–1)
MA 3400 Mathematical Modeling Processes (4–0)
MA 3675/3676 Theory of Functions of a Complex Variable I & II (3–0)

File: handbook.ltx
Requirements set: May 1994
Effective date: October 1994
Minor revisions: 13 Sep 1994

Department of Electrical and Computer Engineering

Course Outlines for EC1010 to EC4910/90

Naval Postgraduate School
Department of Electrical and
Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **2/17/95**
Prepared by: **C. W. Therrien &**
C. C. Cooper
Revised:

EC1010 INTRODUCTION TO MATLAB (1-1)

I. Catalog Description

An introductory course for students with little or no programming background using MATLAB. Basic concepts of the MATLAB environment are considered such as matrix operations, vector and matrix manipulations, equation solving, simulation, programming, and graphing. This course prepares students for using MATLAB in future course work in the ECE department. Graded on a pass/fail basis only.

II. Text and References

Reference

The Student Edition of MATLAB, Version 4, revised edition, The MathWorks, Inc., Prentice-Hall, 1994.

III. Expected Outcomes

An understanding of the MATLAB system environment, commands, and syntax structure; ability to apply MATLAB for programming and problem solving in future ECE courses. More specifically, the student will be able to:

1. Use the built in MATLAB functions to effectively solve problems.
2. Use the graphics capabilities of MATLAB to display results or animate the problem.
3. Program in the MATLAB environment efficiently for the solution of specific problems, or for simulation of systems.

IV. Required Background Experience

1. Mathematics up to calculus.
2. No programming experience is required.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Fundamentals of the MATLAB environment.	1 hr
2.	Matrix and array operations.	1 hr
3.	Vector and matrix manipulations.	1 hr
4.	Data analysis, polynomials, and signal processing.	1 hr
5.	Graphing 2-D and 3-D.	2 hrs
6.	Control flow: loops and branching.	1 hr
7.	M-files: scripts and functions.	1 hr
8.	Data importation and file manipulation.	1 hr
9.	Strings, string macros, and formatted output.	1 hr
10.	Programming techniques with MATLAB.	1 hr
	TOTAL	11 hrs

B. Method of Instruction and Evaluation

A lecture method of instruction is used with assigned programming problems as homework. Completion of all homework is required to receive a "pass" grade in the course.

VI. Computer Usage

Homework and projects require approximately 10-15 hours of computer time, either in the laboratory or on home systems.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 0.5 credit hr (35%) Design: 1 credit hr (65%)

B. Design Content

Students are required to develop short programs and functions that satisfy specified input/output criteria.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are asked to be inventive and efficient in their solution to programming problems. In particular, since MATLAB is an array oriented language, they are asked to find an ``array-oriented'' solution whenever possible. This requires a mode of thinking that is different than when programming in many other high level languages such as FORTRAN or C.

Consideration of alternate solutions:

Again students are asked to find and consider array solutions to problems rather than more conventional element-oriented solutions. Alternate forms of array solutions to problems are illustrated in class lectures. In forming their programs, students are asked to weigh the advantages and disadvantages of a MATLAB ``script'' file that provides user interaction versus a MATLAB ``function'' that simply accepts input values to return output results.

Feasibility consideration:

Since MATLAB is an interpreted language, poorly designed programs in MATLAB (such as those involving multiple loops rather than array operations) can run for hours when presented with large data sets. Careful use of the language is emphasized to reduce execution time, excessive paging, and other system degradation.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **M. Tummala**
Date of Outline Preparation: **2/10/95**
Prepared by: **M. Tummala**
Revised:

EC2010 PROBABILISTIC ANALYSIS OF SIGNALS AND SYSTEMS (3-1)

I. Catalog Description

The foundations of signals and systems are developed from probabilistic and statistical approaches. Emphasis is on signal processing, communication systems, and computer networks relevant to military applications. Topics include probability, random variables and random sequences; density and distribution functions; deterministic versus nondeterministic signals; expectation, the d.c. and the r.m.s. values of nondeterministic signals, correlation and covariance; radar and sonar signal detection; LTI systems, transformation of random variables and the central limit theorem; basic queuing theory and computer communication networks. PREREQUISITE: EC2410 (may be concurrent).

II. Texts and References

Text:

Probability and Random Processes for Electrical Engineering, 2nd Ed., A. Leon-Garcia, Addison-Wesley, 1994.

References:

1. *Probability and Stochastic Processes for Engineers*, C. W. Helstrom, Macmillan, 1991.
2. *Probability, Random Processes, and Estimation Theory for Engineers*, H. Stark and J. W. Woods, Prentice-Hall, 1986.
3. *Fundamentals of Applied Probability Theory*, A. W. Drake, McGraw-Hill, 1988 (reissued).

III. Expected Outcomes

Students learn the basic tools necessary to analyze problems in signals, systems, and computer communication networks using probabilistic and statistical methods.

IV. Required Background Experience

1. Differential and integral calculus.
2. Elementary linear algebra.
3. Basics of signals and systems.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction: signals and systems; overview of typical electrical engineering problems: Communications over noisy channels, signal in noise, system reliability, radar target detection, computer networks, and resource sharing in computer systems. — 2 hrs
2. Basics of probability: events, sample space, and probability; axioms; conditional probability, Bayes' theorem and independence; combinatorics; binomial and Poisson distributions. — 5 hrs
3. Binary communication over a noisy channel: entropy, conditional entropy; P (error), P (no error), and rate of information. — 2 hrs
4. Random variables: probability density and cumulative distribution functions; Chebychev inequality; expectation, d.c. and r.m.s. values; correlation and covariance functions and their properties; sample mean, correlation, and covariance; sequences of random variables and nondeterministic or random signals; characteristic function, z-transform, and moment generating function. — 6 hrs
5. Density functions: Gaussian, uniform, lognormal, and Rayleigh density functions and their use in describing electronic thermal noise, quantization noise, land and sea (radar) clutter, and simple radar target models; Rician density function, envelope of sine wave plus narrowband noise, and propagation in random media (fading); exponential and Weibull density functions and system reliability; Poisson process and the random telegraph signal. — 6 hrs
6. Signal detection: conditional and joint probability density functions; hypothesis testing and application to radar and sonar target detection; single scan and multiscan cases and m out of n detection principle. — 4 hrs
7. Response of systems: LTI system, transformation of random variables; output correlation and density function; envelope detector; convolution, sums of IID random variables, and the central limit theorem. — 4 hrs

8. Basic queuing theory: Markov chain, elements of queuing theory, simple computer communication networks, and resource allocation in computer systems; Little's formula, single and multi-servers. 4 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

Classroom lectures are supplemented with computer demonstrations and projects. The lecture material is tested using at least one midterm exam and a final exam. The computer work typically accounts for 25% of the grade.

VI. Computer Usage

Use of computer simulation to conduct simple experiments on:

1. Binary and communication channel.
2. Probability density and distribution functions.
3. Autocorrelation and crosscorrelation functions.
4. Radar target detection.
5. Simple computer network (basic queuing system).

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

The computer project assignment in this course will be design and simulation of simple binary communication channels and rudimentary discrete LTI systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are encouraged to develop creative solutions to transmission of random binary data using simple binary communication channels. Creative computer coding is required to measure and compare the characteristics of computer generated random sequences with their theoretical counterparts.

Feasibility considerations:

Students experiment with the binary communication channel to study the feasibility of ASCII text transmission under noisy conditions.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Naval Postgraduate School
Department of Electrical and
Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **A. D. Kraus**
Date of Outline Preparation: **4/17/95**
Prepared by: **A. D. Kraus**
Revised:

EC2100 CIRCUIT ANALYSIS (4-2)

I. Catalog Description

The fundamental circuit analysis course for Electrical Engineering majors. The course considers circuit principles, circuit topology, direct current circuits, natural response, forced response, total response, steady-state ac circuits, ac power, frequency response and selectivity, the Laplace transformation, two-port networks and transformers. PREREQUISITES: PH1332, MA1043, and MA1117 (may be concurrent).

II. Text and References

Circuit Analysis, 1st Ed., A.D. Kraus, West Publishing Co., 1991.

III. Expected Outcomes

An understanding of circuit analysis method and the ability to solve circuit problems using the digital computer.

IV. Required Background Experience

1. Mathematics through calculus, including techniques of integration and differentiation.
2. Applications of the derivative and integral.
3. Elementary functions and their graphs.
4. Trigonometric and inverse trigonometric function.
5. Logarithmic and exponential functions.
6. Linear algebra (may be concurrent).
7. General physics which includes force, work, and energy.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Electrical quantities: introduction, definitions and laws, circuit elements, ideal and controlled sources, source transformations, and network topology. — 3 hrs

2. Direct current circuit principles: ladder networks, mesh and node analysis, network theorems.		9 hrs
3. Signals, singularity functions and average and effective values of waveforms.		2 hrs
4. The differential equations of circuit theory: preliminary concepts, existence of the exponential solution, initial conditions, first and second order systems, natural and forced response, forms of solution, zero-input and zero-state response.		4 hrs
5. Impedance concepts, poles and zeros, impulse response, introduction to the s-plane.		3 hrs
6. The Laplace transformation.		6 hrs
7. Steady state ac circuits: introduction to the phasor, ladder networks, mesh and node analysis, the use of the network theorems, frequency response, resonance, power and maximum power transfer.		9 hrs
8. Two-port theory.		4 hrs
9. Exams and holidays.		4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be four comprehensive examinations, including a regularly scheduled final exam.

VI. Computer Usage

The use of PSPICE in circuit analysis.

VII. Laboratory

Laboratory consists of analysis of circuits using PSPICE.

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (65%) Design: 2 credit hrs (35%)

B. Design Content

Homework, examinations, and computer usage involve the selection of network elements and source magnitudes to meet specified responses.

C. Design Attribute

Development of student creativity:

Students perform creative designs of filter networks and conduct analyses to show the implication of variation of the network elements.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **A.D. Kraus**
Date of Outline Preparation: **4/17/95**
Prepared by: **A. D. Kraus**
Revised:

EC2170 ELECTRICAL ENGINEERING FUNDAMENTALS (4-2)

I. Catalog Description

An introductory course for non-electrical engineering majors. The course considers network principles, signal processing circuits, natural response, forced response, total response, steady-state ac circuits, ac power, frequency selectivity, principles of magnetics, magnetic circuits and transformers. PREREQUISITES: PH1111, PH1121, MA1117, and MA1118 or consent of instructor.

II. Text and References

Circuits Analysis, 1st Ed., Kraus, A.D, West Publishing Co., 1991.

III. Expected Outcomes

A solid foundation in circuits and other related electrical systems for the non-electrical engineering major.

IV. Required Background Experience

1. Basic college physics (freshman physics).
2. Differential and integral calculus.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Electrical quantities: introduction, definitions and laws, circuit elements.	3 hrs
2.	Circuit principles: circuit laws, ladder networks, mesh and node analysis, network theorems.	8 hrs
3.	Signals, singularity functions and average effective values of waveforms.	3 hrs
4.	Natural response: first and second-order systems, impedance concepts, poles and zeros.	4 hrs

5. Forced response: response to forcing functions, ac circuit analysis, analogs and dials. — 5 hrs
6. Complete response: general procedure, first and second order circuits, impulse response. — 3 hrs
7. Steady state ac circuits: power calculations, frequency frequency response, resonance, three-phase circuits, maximum power transfer. — 10 hrs
8. Introduction to electro-magnetics and magnetic circuits. — 4 hrs
9. Transformers, mutual inductance, the linear, ideal and real world transformers. — 4 hrs

TOTAL 44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be four comprehensive examinations including a regularly scheduled final exam.

VI. Computer Usage

The use of PSPICE in network analysis.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (65%) Design: 2 credit hrs (35%)

B. Design Content

Homework, examinations, and computer usage involve the selection of network elements and source magnitudes to meet specified responses.

C. Design Attribute

Development of student creativity

Students perform creative designs of filter networks and conduct analyses to show the implications of variation of the network elements.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and
Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **S. Michael**
Date of Outline Preparation: **10/9/94**
Prepared by: **S. Michael**
Revised: **4/28/95**

EC2200 INTRODUCTION TO ELECTRONICS ENGINEERING (3-3)

I. Catalog Description

An introduction to electronic devices and circuits. Solid state physics and semiconductor fundamentals. Properties of p-n junctions in diodes, Bipolar Junction Transistors (BJT) and Field Effect Transistors (FET); static and dynamic models for these devices; and their linear and nonlinear applications. Applications of transistors in the design of amplifiers and digital systems. Ideal operational amplifiers characteristics and applications. Fabrication and the design of integrated circuits. PREREQUISITES: EC2100 or EC2170.

II. Text and References

Microelectronic Circuits, Sedra & Smith, Saunders College Publishing, 1991.

SPICE A Guide to Circuit Simulation and Analysis using PSpice, Prentice-Hall, 1988.

III. Expected Outcomes

Students acquire a qualitative understanding of the charge-carrying mechanisms in crystalline semiconductor p-n junctions. They apply this understanding to the analysis and design of basic diode, bipolar junction transistor, field effect transistor, and ideal operational amplifier circuits.

IV. Required Background Experience

1. Concept of voltage, current, power, signals and sources.
2. Applied analysis of passive circuits.
3. Comprehension of the principle of superposition, Thevenin and Norton equivalents and other network theorems.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Solid state physics and semiconductor fundamentals; electron and hole doping, electrical characteristics.	2 hrs
2.	The p-n junction operation and the diode's electrical characteristics.	2 hrs
3.	Diode circuit applications; circuit models and applications to clipping and rectification; dc power supplies.	3 hrs
4.	Operating principles of the bipolar transistor; transistor parameters, characteristics and modeling.	4 hrs
5.	Transistor applications as amplifier; nonlinear operation as a switch; cutoff and saturation.	5 hrs
6.	FET characteristics, modeling and applications.	4 hrs
7.	MOS, CMOS, and GaAs transistor characteristics, modeling and applications.	5 hrs
8.	Ideal operational amplifiers characteristics and applications.	4 hrs
9.	Integrated circuit fabrication.	1 hr
10.	Exams and review.	3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. This course will have two mid-terms plus a regularly scheduled final exam. Laboratory work constitutes 10% of the final grade.

VI. Computer Usage

Introduction to circuit simulations and device modeling using the SPICE simulation program on personal computers; dc and ac circuit analysis using SPICE.

VII. Laboratory

The laboratory involves measurements of diode, BJT, FET, and OP AMP parameters; analysis, design and simulations of circuit applications.

Most of the experiments are conducted using the Tektronix 2300 series scopes, the Tektronix 576 curve tracers, and the Tektronix TM500 Six Packs.

1.	Measurement of diode operating characteristics: Applications in rectification, clipping, and clamping.	3 hrs
2.	Diode applications in the design and analysis of dc power supplies, filtered, unfiltered, and zener regulated.	3 hrs
3.	Measurement of BJT parameters and operating characteristics both experimentally and using electronic curve tracers.	3 hrs

4. Design and verification of a BJT single and multistage amplifier to assigned specifications, with SPICE verifications. 3 hrs
5. Measurement of JFET parameters and operating characteristics experimentally and using electronic curve tracers. 3 hrs
6. Analysis and design of JFET amplifiers and their biasing techniques. 3 hrs
7. Applications and design of ideal operational amplifier circuits. 3 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%) Design: 2 credit hrs (45%)

B. Design Content

The laboratory exercises in this course involve design of different electronic circuits at the introductory level.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The laboratories require the students to design and construct electronic circuits to meet certain specifications, and then test and verify their design.

Design theory and methodology:

Students study device modelling and use circuit simulation programs (SPICE) to simulate and analyze their designs to verify that they meet the requirements according to the theory.

Use of open ended problems:

There are no unique solutions for the design problems the students are required to do, thus students are faced with open ended choices of components and circuit topologies.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **S. Michael**
Date of Outline Preparation: **4/28/95**
Prepared by: **S. Michael**
Revised:

EC2220 APPLIED ELECTRONICS (2-4)

I. Catalog Description

A project course covering the design and applications of analog and digital integrated circuits (ICs). Includes an introductory overview of important communications ICs and practical experimental design, constructions, and testing of circuits and systems using these devices. PREREQUISITES: EC2200 and EC2500.

II. Text and References

Operational Amplifiers & Linear Integrated Circuits, 4th Ed., R. F. Coughlin and F. F. Driscole, Prentice Hall, 1991.

Operational Amplifiers with Linear Integrated Circuits, 3rd Ed., W. D. Stanley, Macmillan, 1994.

III. Expected Outcomes

This course introduces students to commonly used linear analog integrated circuits in different applications; communications, control, filtering, and computers. The course emphasizes a laboratory approach to develop experimentation techniques and to develop confidence in design, testing and trouble shooting. Topics are selected to reinforce issues in electronics and communication theory.

IV. Required Background Experience

1. Basic electronics through linear amplifiers (i.e., gain, frequency response, feedback, and operational amplifiers).
2. Basic communication concepts through AM, FM and other common modulation techniques.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Overview of linear analog integrated circuits.		1 hr
2. Linear operational amplifiers OPAMPs.		3 hrs
3. Voltage regulators and power supply design.		2 hrs
4. Voltage comparators.		1 hr
5. Timing circuits (monostables, 555 timers).		2 hrs
6. Waveform generation (oscillator, astables, VCOs).		3 hrs
7. A/D and D/A converters.		4 hrs
8. Active filters and analog computers.		3 hrs
9. Analog voltage multipliers.		1 hr
10. Phase locked loops.		2 hrs
	TOTAL	22 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. This course will have one mid-term exam plus a regularly scheduled final exam. Laboratory work will constitute 30% of the final grade and a final project will constitute 20% of the final grade.

VI. Computer Usage

Using computer circuit simulation programs (SPICE) and previously developed device model libraries, the students are required to verify the results of some of the lab experiments and midterm project.

VII. Laboratory

This laboratory addresses the application of linear analog integrated circuits to the design of functional electronic circuits in different applications; communications, control, filtering and computer. A mini-design project that involves most of the studied ICs is also required.

Most of the experiments are conducted using the Tektronix 2300 series scopes, the Tektronix 576 cuve tracers and the Tektronix TM 500 Six Packs.

1. OPAMPs I, II, III.	4 hrs
2. Voltage regulators.	4 hrs
3. 566 Function generator.	4 hrs
4. Voltage comparators and monostable function generators.	4 hrs
5. 555 timers.	4 hrs
6. A/D and D/A converters.	4 hrs
7. Mini-design project.	12 hrs
8. Analog volltage multipliers.	4 hrs
9. Phase locked loops.	4 hrs

VIII. Accreditation

A. Science/Design Mix

Design: 100%

B. Design Content

The laboratory exercises in this course involve design of different electronic circuits in the introductory level.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The laboratories require the students to design and construct electronic circuits to meet certain specifications, and then test and verify their design.

Design theory and methodology:

Students study device modelling and use circuit simulation programs (SPICE) to simulate and analyze their designs to verify that they meet the requirements according to the theory.

Use of open ended problems:

There are no unique solutions for the design problems the students are required to do, thus students are faced with open ended choices of components and circuit topologies.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **A. D. Kraus**
Date of Outline: **4/17/95**
Prepared by: **A. D. Kraus**
Revised:

EC 2270 BASIC ELECTRONICS AND ELECTRICAL MACHINES (4-2)

I. Catalog Description

An introductory course for non-electrical engineering majors and a continuation of EC2170. Topics include fundamentals of electronics, operational amplifiers, fundamentals of semiconductors, diodes and diode circuits, bipolar junction transistors and applications, junction field effect transistors and applications, principles of electromechanics, dc machines and ac machines. PREREQUISITES: EC2170 or consent of instructor.

II. Text and References

Microelectronic Circuits, 3rd Ed., A Sedra, and K. C. Smith, Saunders College Publishing, 1991.

III. Expected Outcomes

A solid foundation in electronics, electronic devices, electrical machinery and other related electrical and electronic systems for the non-electrical engineering major.

IV. Required Background Experience

Electrical engineering fundamentals.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of circuits as applied to electronics, the concept of gain, the gain in dB, Miller's theorem. — 4 hrs
2. Operational amplifiers: inverting and non-inverting configurations, their use as differentiators, integrators, and summing inverters, applications and limitations, analog computers. — 6 hrs
3. Fundamentals of semiconductors: crystal structure, electrons and holes, conduction bands, drift and diffusion. — 4 hrs

4.	Diodes: diode models, diode performance, diode circuits, rectification and rectifiers, zener diodes and their use.	5 hrs
5.	Bipolar junction transistors: principles of operation, biasing and biasing circuits, small signal amplifiers, large signal amplifiers, common emitter, common base and common collector configurations, the transistor as a switch.	6 hrs
6.	Junction field effect transistors: principles of operation, biasing and biasing circuits, small signal amplifiers, large signal amplifiers, RC coupled amplifiers frequency response, multistage amplifiers.	6 hrs
7.	Principles of electromechanics: translational transducers, transducers, rotational transducers, moving iron devices.	3 hrs
8.	Direct current machines: dc generators and dc motors.	4 hrs
9.	Alternating current machines: alternators, synchronous motors, induction motor operation and performance.	6 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be four comprehensive examinations including a regularly scheduled final exam.

VI. Computer Usage

None

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (60%) Design: 2 credit hrs (40%)

B. Design Content

Homework, examinations, and computer usage involve the selection of network elements and source magnitudes to meet specified criteria.

C. Design Attribute

Development of student creativity:

Students perform creative designs of op-amp networks, biasing circuits, device selection, and conduct analyses to show the implication of variation of the network and devices.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. Cristi**
Date of Outline: **11/21/94**
Prepared by: **R. Cristi**
Revised:

EC2300 CONTROL SYSTEMS (3-2)

I. Catalog Description

The main subject of this course is the analysis of feedback systems using basic principles in the frequency domain (Bode plots) and in the s-domain (root locus). Performance criteria in the time domain such as steady-state accuracy, transient response specifications, and in the frequency domain such as bandwidth and disturbance rejection, will be introduced. Simple design applications using root locus and Bode plot techniques will be addressed in the course. Laboratory experiments are designed to expose the students to testing and evaluating mathematical models of physical systems, using computer simulations and hardware implementations. PREREQUISITE: EC2100, EC1010 or equivalent.

II. Text and References

Analog and Digital Control System Design, C. T. Chen, Saunders College Publishing, 1993.

III. Expected Outcomes

Students are expected to acquire the capability to analyze and design relatively simple automatic control systems through the use of mathematical, graphical, and computer techniques, and to become proficient in developing mathematical models from laboratory measurements.

IV. Required Background Experience

1. Laplace transform solution of ordinary differential equations.
2. Basic knowledge of MATLAB.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Mathematical preliminaries: models for physical systems, linear time invariant systems, zero input-zero state response, — 6 hrs

block diagram representations.

2. Block diagram models for physical systems: DC motors, transducers, operational amplifiers, manipulations of block diagrams. — 6 hrs
3. Quantitative and qualitative analyses of control systems: first and second order systems time response, stability, steady state response with sinusoidal inputs. — 4 hrs
4. Design criteria, physical constraints and feedback: performance criteria of closed loop systems, steady state response of unity feedback systems and system types, disturbances, proper compensators. — 4 hrs
5. The root locus method: desired pole regions for first and second order systems, basic rules for plotting the root locus, design using root locus, PD compensators, phase lead and phase lag networks. — 6 hrs
6. Frequency domain techniques: Bode plots, Nyquist plots and closed loop stability, frequency domain specifications, design using Bode plots, phase lead and PI compensators. — 7 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 30% of the final grade.

VI. Computer Usage

Both laboratories and the class projects are based on the MATLAB package in particular, using the graphical interface SIMULINK.

VII. Laboratory

Working in groups of two, the students are asked to perform three classes of experiments:

1. Numerical experiments using MATLAB.
2. Measurements of systems components to determine the mathematical model, and the use of computer simulation techniques to verify the accuracy of the model.
3. Design of an analog controller based on operational amplifiers to satisfy given performance specifications.

VIII Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

The laboratory exercises in this class are all project type and involve the analysis of mathematical models for physical systems, with application to simple design techniques.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Develop of student creativity:

Each student is required to use root locus and frequency response techniques to design feedback control systems to satisfy performance specifications.

Use of open ended problems:

The techniques learned (root locus and frequency response) are completely open ended and yield non-unique solutions.

Formulation of design problem statements and specifications:

Design problems in this course are based on standard engineering specifications.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other

military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Systems Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. Cristi**
Date of Outline: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC2320 LINEAR SYSTEMS (3-1)

I. Catalog Description

Formulation of system models including state equations, transfer functions, and system diagrams for continuous and sampled-data systems. Computer and analytical solution of system equations. Stability, controllability, and observability are defined. Introduction to design by pole placement using measured and estimated state feedback. Application to military systems is introduced via example. PREREQUISITE: EC2100.

II. Text and References

Analog and Digital Control Systems Design, C. T. Chen, Saunders College Publishing, 1993.

III. Expected Outcomes

Students are expected to acquire the capability to model and analyze linear multivariable systems using state space methods an to use algebraic techniques in conjunction with computer tools to design control systems.

IV. Required Background Experience

1. Laplace transform and classical solution of differential equations.
2. Fundamentals of linear algebra.
3. Basic programming experience.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	State space models of continuous time systems.	4 hrs
2.	Economical realizations and computer solutions.	3 hrs
3.	Controllability, pole placement by state feedback.	6 hrs
4.	Observability, state estimators.	4 hrs
5.	Pole placement by estimated state.	3 hrs

6. State space models for sampled data systems.		3 hrs
7. The unilaterial z-transform and linear difference equations.		4 hrs
8. Pole placement for sampled data systems.		3 hrs
9. Digital implementation of analog compensation.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used, also involving computer projects. There will be at least one exam plus a regularly scheduled final exam. Generally, computer project work will constitute 10 to 20% of the final grade.

VI. Computer Usage

Several computer projects are assigned using MATLAB and Simulink to emphasize design tools and computer simulations.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer projects assigned in this class involve the simulation of modeling and control techniques developed in class. The students are required to write their own computer code.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to develop state space equations for physical systems, design control techniques to meet given specifications (by pole placement), and simulate the behavior of the open and closed loop system.

Use of open ended problems:

The techniques learned (pole placement by state feedback) are completely open ended and yield non-unique solutions.

Formulation of design problem statements and specifications:

Design problems in this course are based on standard engineering specifications.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **M. Tummala**
Date of Outline: **2/17/95**
Prepared by: **M. Tummala**
Revised:

EC2400 DISCRETE SYSTEMS (3-1)

I. Catalog Description

Principles of discrete systems, including modeling, analysis and design. Topics include difference equations, convolution, stability, bilateral z-transforms and application to right-sided and left-sided sequences, system diagrams and realizations, and frequency response. Simple digital filters are designed and analyzed. PREREQUISITE: MA2051 (may be concurrent) and ability to program in high level language or very high level language (e.g., MATLAB).

II. Text and References

First Principles of Discrete Systems and Digital Signal Processing, Strum and Kirk, Addison Wesley, 1988

III. Expected Outcomes

Students will acquire the capability to model and analyze linear time invariant systems through the use of mathematical and computer techniques and to design simple digital filters by pole-zero placement.

IV. Required Background Experience

1. Experience with writing computer code in MATLAB or in a high level language.
2. Algebra and calculus for variables.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Sequences.	2 hrs
2. Sampling theorem.	1 hr
3. Systems and their properties.	2 hrs
4. Solution of linear constant-coefficient difference equations.	1 hr
5. Unit impulse response and convolution.	3 hrs
6. System diagrams.	1 hr

7. Stability and the initial condition response. 1 hr
8. Total response of LTI systems. 2 hrs
9. Frequency response and the discrete time Fourier transform. 5 hrs
10. Ideal filters. 2 hrs
11. Graphical design and analysis of filters. 3 hrs
12. Bilateral z-transforms and the residue theorem. 8 hrs
13. Signal flow graphs and Mason's gain rule. 2 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

Instruction consists of lectures and computer demonstrations. Computer assignments are used to supplement the classroom lectures. The lecture material is tested using at least on midterm exam and a final exam. Computer projects typically account for 30% of the final grade.

VI. Computer Usage

Computer demonstrations are used in the classroom to present the digital filter design and analysis. Computer projects utilizing MATLAB or C are assigned:

1. Discrete sequences
2. Numerical solution of difference equations.
3. Discrete convolution.
4. Discrete system frequency response.
5. Digital filter design.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer projects assigned in this course involve design of digital filters (lowpass, highpass, bandpass, and notch) using a graphical approach that requires placing the system poles and zeros in the complex plane in order to achieve the requisite performance. It is an intensive trial and error approach to designing digital filters.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Digital filter design using graphical approach requires creative ways of placing poles and zeros to achieve required magnitude and phase response in filter design.

Use of open ended problem:

Design of digital filters is an open ended problem. Students are encouraged to explore advanced methods of filter design with the goal being either sharp magnitude response or linear phase response.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

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Course Coordinator: **R. Cristi**
Date of Outline: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC2410 ANALYSIS OF SIGNALS AND SYSTEMS (3-1)

I. Catalog Description

Analysis of digital and analog signals in the frequency domain; properties and applications of the discrete Fourier transform, the Fourier series, and the continuous Fourier transform; analysis of continuous systems using convolution and frequency domain methods; applications to sampling, windowing, and amplitude modulation and demodulation systems. PREREQUISITE: EC2400.

II. Text and References

Signals and Systems, A. V. Oppenheim and A. S. Willsky, Prentice-Hall, 1983

or

Introduction to Fourier Analysis, N. Morrison, Wiley, 1986.

III. Expected Outcomes

An understanding of frequency domain techniques in the analysis of signals and systems. The ability to analyze signals characteristics using commonly used computer tools (such as the FFT). An introductory knowledge of applications in communications engineering, such as amplitude modulation and demodulation.

IV. Required Background Experience

1. Linear difference equations.
2. Frequency response of discrete systems.
3. System response using z-transforms and convolution.
4. Cascade and parallel realizations of discrete systems.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. The Discrete Fourier Transform (DFT) and applications. 6 hrs

2. Fourier series.		4 hrs
3. The continuous Fourier transform (CFT).		4 hrs
4. The relationship between the DFT and the CFT.		2 hrs
5. Sampling.		2 hrs
6. Windowing.		2 hrs
7. Continuous convolution and linear systems.		5 hrs
8. Frequency response of continuous linear systems, filtering.		4 hrs
9. Amplitude modulation and demodulation.		2 hrs
10. Exams and holidays.		2 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used, also involving computer projects. There will be at least one exam plus a regularly scheduled final exam. Generally, computer project work will constitute 10 to 20% of the final grade.

VI. Computer Usage

Several computer projects are assigned to emphasize the use of computer tools (such as MATLAB) in spectral analysis of sampled signals.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer projects assigned in class address the problem of analyzing continuous time signals using discrete time techniques, such as the Fast Fourier Transform (FFT).

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to apply Fourier decomposition techniques in order to predict the response of linear time variant systems to periodic inputs and to analyze the spectral components of continuous time signals.

Use of open ended problems:

The use of the FFT lends itself to a number of possible non-unique interpretations. The student is made aware of strengths and limitations of the tools and the techniques themselves.

Formulation of design problem statement and specifications:

Design problems of this course are based on standard engineering specifications.

IX. Educational Skill Requirements (ESRs)

This Course supports the follows ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. Cristi**
Date of Outline: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC2450 ACCELERATED REVIEW OF SIGNALS AND SYSTEMS (4-0)

I. Catalog Description

An advanced review of continuous and discrete system theory intended for students who have previous education in these areas. Topics covered by each student will depend upon background and competence in the subject matter of EC2400, EC2410, and EC2320. PREREQUISITE: Sufficient background in linear systems theory. Graded on Pass/Fail basis only.

II. Text and References

Selected from the texts used in EC2320, EC2400, and EC2410.

III. Expected Outcomes

This course is intended for those students who have previously studied the various aspects of linear systems theory. Expected outcomes correspond to those of EC2320, EC2400, and EC2410.

IV. Required Background Experience

Prior exposure to all or most of the topics of EC2320, EC2400, and EC2410.

V. Detailed Description of the Course

A. Expanded Description of the Course

Selected from the topics of EC2320, EC2400, EC2410. Selection depends on the background and experience of the students.

B. Method of Instruction and Evaluation

A lecture mode of instruction is used, also involving computer projects. There will be at least one exam plus a regularly scheduled final exam.

Generally, computer project work will constitute 10 to 20% of the final grade.

VI. Computer Usage

See EC2320, EC2400, and EC2410.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%)   Design: 1 credit hr (25%)

B. Design Content

The computer projects assigned in this class involve the simulation of modeling and control techniques developed in class. The students are required to write their own computer code.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to apply modeling techniques to physical problems and predict the response to various input signals by computer simulations. Also, the student has to use frequency domain techniques to characterize signals.

Use of open ended problems:

Many of the techniques used do not have unique solutions.

Formulation of design problem statements and specifications:

Design problems in this course are based on standard engineering specifications.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **R. C. Robertson**
Date of Outline Preparation: **2/7/95**
Prepared by: **R. C. Robertson**
Revised:

EC2500 COMMUNICATIONS SYSTEMS (3-2)

I. Catalog Description

In this first course on the electrical transmission of signals, the theory, design, and operation of analog and digital communication systems are investigated. Included are A/D conversion, modulation, demodulation, frequency division multiplexing, and time-division multiplexing. PREREQUISITES: EC2200 and EC2410.

II. Text and References

An Introduction to Analog and Digital Communications, Simon Haykin, Wiley, 1989.

or

Introduction to Communication Systems, 3rd. ed., F. G. Stremler, Addison-Wesley, 1990.

or

Communications Systems, 3rd. Ed., S. Haykin, Wiley & Sons, 1994.

III. Expected Outcomes

A knowledge of time and frequency descriptions of analog and digital messages in communications. To explain sampling and pulse modulation which may occur prior to message transmission. Understanding of the time and frequency descriptions of amplitude modulation and angle modulation and the implementation of modulators, demodulators, and waveform recovery techniques.

IV. Required Background Experience

Mathematics through calculus and differential equations, Fourier transform, dc and ac circuit analysis, basics of modern electronics, basics of linear systems and filtering, sampling and the sampling theorem.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Introduction: review of frequency response methods, Fourier transforms, convolution, linear system response, filters, bandwidth, complex low-pass signal representation.	4 hrs
2.	Linear modulation techniques: AM, DSB, SSB, VSB; time and frequency domain signal representations, transmission bandwidth, modulators, coherent and noncoherent demodulators.	7 hrs
3.	Angle modulation techniques: frequency and phase modulation; time and frequency domain signal representations, transmission bandwidth; modulators; phase-locked loops and demodulators.	7 hrs
4.	Pulse code modulation (PCM), differential PCM, delta modulation, quantization noise, companding.	5 hrs
5.	Digital modulation techniques: BFSK, BPSK, ASK, baseband and passband and waveforms, transmission bandwidth, coherent and noncoherent demodulators.	5 hrs
6.	Frequency-division multiplexing, time-division multiplexing, and applications to mobile and satellite communications.	3 hrs
7.	Exams and holidays.	<u>2 hrs</u>
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will generally be two exams plus a regularly scheduled final exam.

VI. Computer Usage

Homework and/or projects are assigned that utilize MATLAB and/or the SPC toolbox.

VII. Laboratory

The laboratory provides the student with an opportunity to observe spectra of selected waveforms and to measure the transfer function of an RC low pass filter.

Experiments:

1.	Introduction to the FFT spectrum analyzer.	2 hrs
2.	Transfer function of the RC lowpass filter, delta function spectrum, and response of the RC lowpass filter.	2 hrs
3.	Amplitude modulation spectra.	2 hrs
4.	Frequency modulation spectra.	2 hrs

Instrumentation includes function generators (modulators), dual trace oscilloscopes, and spectrum analyzers.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%)   Design: 1 credit hr (25%)

B. Design Content

Students learn how to design an analog communication system given the inherent trade offs in power, bandwidth, and system complexity.

C. Design Attribute

Consideration of alternate solutions:

Students must learn how to select an analog communication system for a specific application such that power and bandwidth requirements are met.

IX. Educational Skill Requirements(ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **R. Janaswamy**
Date of Outline Preparation: **3/16/95**
Prepared by: **R. Janaswamy**

EC2600 ELECTROMAGNETIC FIELDS AND WAVES (4-0)

I. Catalog Description

Static field theory is developed from physical and mathematical principles. Time-varying Maxwell equations are developed and solutions to the wave equations are presented. Additional topics include boundary value problem solutions, and plane wave propagation in vacuum and materials. PREREQUISITE: MA2051 or equivalent.

II. Text and References

Elements of Electromagnetics, 2nd Ed., Sadiku, Saunders College Pub., 1994.

or

Field and Wave Electromagnetics, 2nd Ed., Cheng, Addison-Wesley, 1989.

III. Expected Outcomes

Students will learn how to apply Maxwell's equations as a basis for future studies of radiation, scattering, wave propagation and microwave circuits, devices and systems.

IV. Required Background Experience

1. Calculus, including vector calculus.
2. College level general physics, including electromagetics.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of vector calculus, line and surface integrals.	6 hrs
2. Coulomb's law and electrostatic field equations.	9 hrs
3. Boundary value problem solutions.	3 hrs
4. Biot-Savart law and magnetostatics.	9 hrs

5. Wave equations, potential equations, Poynting's theorem.		6 hrs
6. Plane wave propagation, skin effect, polarization.		6 hrs
7. Exams and review.		5 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

Instruction consists of in-class lectures. Homework assignments, aimed at aiding the students' understanding of basic concepts, are handed out periodically and graded. Students are evaluated on a regular basis through at least two mid-term exams and one comprehensive final exam.

VI. Computer Usage

Students are encouraged to use computers for solving selected homework problems involving static field boundary value problems and wave propagation, including propagation losses and skin-depth.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (100%)

B. Design Content

None

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. Janaswamy**
Date of Outline Preparation: **3/16/95**
Prepared by: **R. Janaswamy**
Revised:

EC2610 ELECTROMAGNETIC ENGINEERING (3-1)

I. Catalog Description

A continuation of EC2600. Topics include the analysis and design of transmission lines, waveguides, resonators, and high frequency components. Applications of military and other interest are presented in the laboratory. PREREQUISITE: EC2600.

II. Text and References

Field and Wave Electromagnetics, 2nd Ed., Cheng, Addison-Wesley, 1989.

or

Elements of Electomagnetics, 2nd Ed., Sadiku, Saunders College Pub., 1994.

III. Expected Outcomes

Students will develop a qualitative understanding of the characteristics, capabilities and limitations of those wave guiding structures which are important for connecting antennas to transmitting and receiving systems and for building microwave circuits. This understanding is achieved by developing a quantitative ability to calculate characteristics of lines and guides and through comparative studies of structures.

IV. Required Background Experience

Vector calculus, Maxwell's equations, plane waves.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Lumped vs. distributed circuits and applications of distributed circuits.	1 hr
2. Circuit model of TEM mode transmission line.	1 hr
3. Transient analysis of transmission line.	4 hrs
4. Steady state analysis of transmission line.	10 hrs

5. Transmission line components.		2 hrs
6. Waveguides.		8 hrs
7. Waveguide components.		2 hrs
8. Cavities.		5 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. The course will have at least two mid-term exams and one comprehensive final exam.

VI. Computer Usage

Students are introduced to a microwave design workstation.

VII. Laboratory

The goal of this laboratory is to familiarize the student with high frequency components and measurement techniques.

1. Pulses on transmission lines.	2 hrs
2. Slotted line impedance measurements.	2 hrs
3. Transmission line resonator.	2 hrs
4. Waveguide components.	2 hrs
5. Cavity resonators.	2 hrs
6. Network analysis and design workstation.	1 hr

Systems: microwave design workstation, scalar and vector network analyzer.

Instruments: signal generators, oscilloscope, power meters, SWR meter.

Components: slotted line, directional couplers, loads, attenuators, circulators, isolator, frequency meter.

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

Students design RF components to the required specifications in the lecture content of the course. Laboratory experiments provide hands on experience with instrumentation/measurement techniques needed in the design.

C. Design Attribute

Realistic constraints on design:

Students design various RF components such as single/double stub matching sections, waveguides, resonators, etc., subject to realistic design constraints such as mismatch losses, overall size, bandpass characteristics, and power carrying capacities.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **H-M. Lee**
Date of Outline Preparation: **1/27/95**
Prepated by: **H.-M. Lee**
Revised:

EC2650 ACCELERATED REVIEW OF ELECTROMAGNETICS (4-2)

I. Catalog Description

A comprehensive review of basic electromagnetic theory intended for students who have previously studied the subject matter of EC2600 and EC2610. PREREQUISITE: Sufficient background in electromagnetic theory. Graded on Pass/Fail basis only.

II. Text and References

Field and Wave Electromagnetics, 2nd Ed., Cheng Addison-Wesley, 1989.

III. Expected Outcomes

This course provides accelerated coverage of the material presented in courses EC2600 and EC2610 and is intended for those students who have previously studied electromagnetic theory. Expected outcomes are the same as those for EC2600 and EC2610.

IV. Required Background Experience

Prior exposure to most or all the topics of EC2600 and EC 2610.

V. Detailed Description of the Course

A. Expanded Description of the Course

Selected from the topics of EC2600 and EC2610. Selection depends on student backgrounds and experience.

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. A midterm exam and a final exam are given. A computer based design project is assigned. Laboratory work constitutes 40% of the final grade.

VI. Computer Usage

Students are encouraged to use computers for solving selected homework problems involving tedious formula calculations, such as propagation losses and wavelength in lossy materials and the estimation of waveguide mode and parameters.

VII. Laboratory

The goal of this laboratory is to familiarize the student with high frequency components and measurement techniques.

1. Pulses on a transmission.	2 hrs
2. Impedance measurements.	2 hrs
3. Waveguide impedance measurements.	2 hrs
4. Cavity resonators.	2 hrs

Instruments: signal generators, oscilloscope, power meters, SWR meter.

Components: coaxial and waveguide slotted lines, directional couplers, loads, attenuators, circulators, isolator, frequency meter, irrs, waveguide sections.

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (80%) Design: 1 credit hr (20%)

B. Design Content

Students are asked to consider the problem of communicating with a ship moving away until well over the horizon. They are asked to specify realistic transmitter power and receiver sensitivity to achieve a satisfactorily high percentage of channel availability.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Formulation of design problem statement and specifications:

Students are asked to formulate the design problem in terms of requirements for achieving a satisfactorily high availablity of communication channels.

Feasibility considerations:

Students are required to consider the feasibility of their design in terms of equipment currently available to the Navy.

Consideration of alternative solutions:

Students are asked to propose and evaluate alternative solutions such as the utilization of multiple frequencies and various polarization schemes.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

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Course Coordinator: **J. T. Butler**
Date of Outline Preparation: **2/17/95**
Prepared by: **J. T. Butler**
Revised:

EC2800 INTRODUCTION TO MICROPROCESSORS (3-2)

I. Catalog Description

An introduction to the organization and operation of microprocessing and microcomputers, both key embedded elements of military systems. Topics include: the instruction set, addressing methods, data types and number systems, stack and register organization, exception processing, assembly language programming techniques including macros, assembly language implementation of typical control structures, data structures, and subroutine linkage methods. Laboratory sessions teach a systematic method for program design and implementation. The laboratory assignments consists of a series of programs which collectively implement a major software project. PREREQUISITIES: A high level language and EC2820 (may be concurrent).

II. Text and References

68000 Family Assembly Language, A. Clements, PWS Publishers, 1994.

III. Expected Outcomes

An understanding of the organization of microprocessors, microprocessor instruction sets, data types, stack and register organization, and exception processing. A familiarization with assembly language programming techniques including macros and conditional assembly. A knowledge of the assembly language implementation of typical control structures, data structures, sorting and searching, and subroutine linkage methods.

IV. Required Background Experience

1. Computer algorithms.
2. Control structures such as loops and conditional transfers.
3. Data types and data organization.
4. Subprograms and parameter passing.
5. Combinational logic circuits.
6. Sequential logic circuits.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction, binary numbers, hex numbers, two's complement, overflow, ASCII, addition/subtraction.	4 hrs
2. Architecture of the 68000.	2 hrs
3. Basic 68000 intructions and addressing modes.	5 hrs
4. Assembler syntax and assembler directives.	2 hrs
5. Assembler macros.	2 hrs
6. Advanced 68000 instructions and addressing modes.	4 hrs
7. Subroutines and parameter passing.	3 hrs
8. Sorting and searching, trees.	4 hrs
9. 68000 pinout, read/write cycle.	2 hrs
10. Exception handling.	1 hr
11. Exams and holidays.	4 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

This is a lecture course (3 hrs/week) with a laboratory (2 hrs/week). Students take two exams, one final, and submit laboratory reports. Laboratory work represents about 30% of the grade.

VI. Computer Usage

All laboratory work involves assembly language programming. Programs are assembled and linked on an HP 64700A Emulator System. Each set up has complete hardware and software for system design. Associated with each HP 64700A is a SUN workstation.

VII. Laboratory

The objective of the laboratory is to teach a systematic method for program design and implementation. The laboratory project consists of a series of six assignments which collectively implement a basic 68000 monitor.

1. Familiarization with the SUN workstation.	1 week
2. Familiarization with the HP 6700A.	1 week
3. Development of a basic monitor for the 68000:	
a. Basic character manipulation.	1 week
b. Advanced character manipulation.	1 week
c. Command decoding subprograms.	1 week
d. Subprogram to extract a token from a string.	2 weeks
e. Subprograms to convert between binary and ASCII.	1 week

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

Design of a basic 68000 monitor serves as the basis for this course. Students produce parts of the monitor in each lab and assemble it at the end of the course.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are required to produce a basic 68000 monitor, given specifications. Creativity is required to 1) produce a working program and 2) to do so with a reasonable number of instructions.

Development and use of modern design theory and methodology:

Good programming practices are emphasized throughout the course, including analyzing the problem, decomposing it into parts and merging the parts together. Top down and bottom up approaches are discussed. Structured programming is discussed.

Formulation of design problem statement and specifications:

Students learn to analyze a given specification and to convert that to a working program. They are required to provide adequate comments on their program. Example programs are discussed, so students learn the standards associated with good program documentation.

Consideration of alternative solution:

Students must choose between alternative ways to design a program.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **J. T. Butler**
Date of Outline: **2/17/95**
Prepared by: **J. T. Butler**
Revised:

EC2820 DIGITAL LOGIC CIRCUITS (3-2)

I. Catalog Description

An introductory course in the analysis and design of digital circuits. These circuits are the basis for all military computers and digital control systems. No previous background in digital concepts or electrical engineering is assumed. Topics include: Boolean algebra, truth tables, logic gates, integrated circuit families, decoders, multiplexers, arithmetic circuits, PLAs, ROMs, design of combinational circuits using SSI and MSI components, sequential logic including latches, flip-flops, registers, counters, and memories, analysis and design of synchronous circuits using state tables and state diagrams. The laboratories are devoted to the study of combinational and sequential circuits using state tables and state diagrams. The laboratories are devoted to the study of combinational and sequential circuits and include a sequence of design projects involving increasingly complex digital functions. PREREQUISITES: None

II. Text and References

Digital Circuits and Microprocessors, H. Taub, McGraw-Hill, 1982

III. Expected Outcomes

An understanding of digital circuits and methods for their design and analysis. A familiarization with the common commercial MSI circuits and their use. An understanding of the various types of digital memories. An understanding of a spectrum of digital circuit design tools ranging from classical methods to the use of MSI circuits and programmable logic devices.

IV. Required Background Experience

None

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Logic signals and logic circuits; logic gates: NOT, OR, 3 hrs

AND, NOR, NAND, and EXCLUSIVE-OR.

2.	Logic functions and Boolean algebra.	3 hrs
3.	Classical methods for synthesis of minimal circuits; Karnaugh maps and Quine-McCluskey.	4 hrs
4.	Sequential network building blocks RS and D latches, clocked RS, D, and JK flip-flops.	2 hrs
5.	Analysis of sequential circuits; classical methods for synthesis of sequential circuits.	3 hrs
6.	Storage registers, shift registers, and counters.	2 hrs
7.	Characteristics of IC Families: power consumption, logic levels, and gate delays; types of outputs: totem pole, open collector, and 3-state.	3 hrs
8.	Mixed logic: assertion levels and symbolic notation.	1 hr
9.	MSI combinational circuits: decoders, encoders, and multiplexers; synthesis of combinational and sequential circuits using MSI components.	3 hrs
10.	Arithmetic circuits; carry lookahead.	4 hrs
11.	Programmable logic devices: PROMs, PLAs, PALs, and EPLDs.	1 hrs
12.	Exams and holidays.	4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

This is a lecture course (3 hrs/week) with a laboratory (2 hrs/week). Students take two exams, one final, submit homework, and submit laboratory reports.

VI. Computer Usage

None. This course focuses on computer circuits.

VII. Laboratory (including major items of equipment and instrumentation used)

The goal of the laboratories is to familiarize students with the operation of common SSI and MSI circuits, to introduce them to digital circuit design and testing, and to acquaint them with an array of debugging techniques. Laboratory circuits are constructed from standard SSI and MSI LSTTL circuits mounted on a Hewlett Packard 5035T Logic Lab equipped with a Hewlett Packard 10525 Logic Prode.

1.	Logical functions of two variables.	1 week
2.	Latches and flip-flops.	1 week
3.	Shift registers.	2 weeks
4.	Counters.	2 weeks
5.	Adders and number systems.	1 week

6. Sequential circuit design: T-bird. 2 weeks
7. Shift register controller design. 2 weeks

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

Design of basic logic circuits using SSI and MSI components. Students are asked to design specified logic circuits and to implement their designs in the laboratory.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are required to use skills taught in class to create circuit designs from specifications. Creative circuit designs are analyzed and students are encouraged to be creative in the laboratory projects.

Development and use of modern design theory and methodolgy:

Students are taught methods of design for both combinational and sequential circuits. Methods best suited to large-scale design are taught in addition to methods for small scale design. They are required to apply these techniques in the laboratory and homework.

Formulation of design problem statement and specifications:

Students learn to analyze a circuit specification and to translate that to a working circuit. They are asked to document their designs effectively improving their communication with an end user.

Consideration of alternative solution:

Students are shown in class alternative design methods (e.g., Karnaugh map versus Quine-McCluskey design techniques). This is done in the context of a discussion of relative merit and tradeoffs. Students choose alternate methods in their laboratories.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **F. W. Terman**
Date of Outline Preparation: **2/23/95**
Prepared by: **F. W. Terman**
Revised:

EC2890 DIGITAL CIRCUIT DESIGN LABORATORY (0-6)

I. Catalog Description

A laboratory course in the design of digital circuits. Several projects with relevance to naval and other military applications will be completed involving design with MSI components and hardware and software control of external events with a microprocessor. Students are free to choose their projects according to their interests. PREREQUISITE: EC2800.

II. Text and References

Logic Design Projects Using Standard Integrated Circuits, John F. Wakerly, John Wiley & Sons, 1976.

III. Expected Outcomes

An opportunity to use the material learned in previous courses to design, construct, and test digital circuits. The course aims to provide a flexible design environment with some structure and with technical assistance readily available when needed.

IV. Required Background Experience

1. Design methods for combinational circuits.
2. Design methods for sequential circuits.
3. Familiarity with common MSI devices.
4. Characteristics of real circuits: gate delays, setup and hold times, fan out, hazards.
5. Microcomputer organization.
6. Assembly language programming.

V. Detailed Description of the Course

A. Expanded Description of the Course

The course consists entirely of the laboratory projects listed in Part VII below.

B. Method of Instruction and Evaluation

Instruction consists of guidance, as required, in the selection and completion of the laboratory projects. Evaluation is through a demonstration by the student of each completed project and a written report on it.

VI. Computer Usage

The final laboratory project involves programming the Motorola 68000 microprocessor as well as interfacing external hardware to it.

VII. Laboratory

The first two projects are constructed on a Hewlett Packard 5035T Logic Lab equipped with a Hewlett Packard 10525 Logic Probe. The final project uses the Hewlett-Packard 64700A Development System with a Motorola 68000 emulation pod.

1. Any of Wakerley's "C-series two week projects."	2 weeks
2. Any of Wakerley's "E-series four week projects."	4 weeks
3. A project of the student's choice using the Motorola 68000 and the HP 64700A Development System. The project must exercise an input port and an output port in addition to the ports connected to the terminal.	5 weeks

VIII. Accreditation

A. Science/Design Mix

Design: 3 credit hrs (100%)

B. Design Content

Projects 1 and 2 consist of designing and constructing solutions to specified problems. Project 3 adds the specification of the problem to be solved.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The purpose of this laboratory is to develop student creativity through a series of projects with progressively less structure. The instructor will provide feedback, as needed, to ensure that the student does not limit him or herself to a ``brute force'' solution to the projects undertaken.

Consideration of alternative solutions:

The projects undertaken require, by their nature, an investigation of alternative solutions.

Feasibility considerations:

The solutions to be constructed must be feasible, both from the standpoint of available materials and equipment and also from the standpoint of available instruments for testing and debugging.

Formulation of design problem statement and specifications:

For the third project, the student must decide on the apparatus to be interfaced to the 68000 microprocessor and provide specifications for how the apparatus is to operate.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications

systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **J. P. Powers**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC2990 DESIGN PROJECTS IN ELECTRICAL ENGINEERING (0-8)

I. Catalog Description

Design projects under the supervision of faculty members. Individual or team projects involving the design of devices or systems. Projects will typically be in support of faculty members. PREREQUISITE: Consent of instructor. Graded on Pass/Fail basis only.

II. Text and References

None

III. Expected Outcomes

Student or student teams (maximum of three) devise a system, component, or algorithm to meet a requirement.

IV. Required Background Experience

Electronic systems, systems and controls, signal processing, communications, computer engineering, or electromagnetics (as required by selected project).

V. Detailed Description of the Course

A. Expanded Description of the Course

Analysis of requirements, synthesis of two or more design solutions, evaluation of solutions, and preparation of engineering report.

B. Method of Instruction and Evaluation

According to content, along the lines of regularly scheduled 2000 level courses in the ECE Department.

VI. Computer Usage

As appropriate to selected project.

VII. Laboratory

As required by selected project.

VIII. Accreditation

A. Science/Design Mix

Design: 4 credit hrs (100%)

B. Design Content

This is a project design course.

C. Design Attributes

Various, depends on particular offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
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Course Coordinator: **A. D. Kraus**
Date of Outline Preparation: **4/17/95**
Prepared by: **A. D. Kraus**
Revised:

EC3100 ADVANCED CIRCUIT ANALYSIS (3-2)

I. Catalog Description

A graduate level course in circuit and network analysis. The course considers three-phase power systems, mutual inductance and transformers, network functions, stability, convolution, the general network method, and an introduction to network synthesis. PREREQUISITE: EC2100.

II. Text and References

Circuit Analysis, Kraus, A. D., West Publishing Company, 1991.

III. Expected Outcomes

The ability to solve advanced circuit problems using the digital computer.

IV. Required Background Experience

1. Basic college physics (freshman physics).
2. Differential and integral calculus.
3. A first course in circuit analysis.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Three phase power systems, the single phase three-wire system, three phase fundamentals, the balanced delta and wye connections, the effect of imbalance and power considerations.	6 hrs
2.	Mutual inductance, transformers, the ideal, linear and real world transformers, impedance transformation and impedance matching.	5 hrs
3.	Network functions, stability, Routh-Hurwitz criterion, frequency response revisited.	4 hrs
4.	Convolution in the time and s-domains: indicial admittance,	3 hrs

Borel's theorem, duHamel's theorem, graphical convolution.

5.	The general network method, additional topology considerations, fundamental loop and cut set matrices, mesh, loop, node and cut set analysis, power by quadratic form.	6 hrs
6.	Introduction to network synthesis, positive real functions, first order networks, Foster and Cauer forms, second order networks.	5 hrs
7.	Exams and holidays.	4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be four comprehensive examinations including a regularly scheduled final exam.

VI. Computer Usage

Use of PSPICE in circuit analysis.

VII. Laboratory

1. Frequency selectivity and resonance.
2. Filters.
3. Maximum power transfer.
4. Impedance matching.
5. Power transformer.
6. Three phase system parameters.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Homework, examinations, and computer usage involve the selection of network elements and source magnitudes to meet specified responses.

C. Design Attribute

Development of student creativity:

Students perform creative designs of filter networks and conduct analyses to show the implication of variation of the network elements.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **J. G. Ciezki**
Date of Outline Preparation: **2/8/95**
Prepared by: **J. G. Ciezki**
Revised:

EC3130 Electrical Machinery Theory (4-2)

I. Catalog Description

An introduction to the analysis of magnetically-coupled circuits, dc machines, induction machines, and synchronous machines. The course will include explicit derivations of torque, voltage, and flux linkage equations, formulation of steady-state circuits, development of reference frame theory, and the basics of machine simulation as required in shipboard electric drive analysis. PREREQUISITES: EC2270 or EC3100.

II. Text and References

Electromechanical Motion Devices, P. C. Krause and O. Wasynczuk, McGraw-Hill, 1989.

III. Expected Outcomes

Students will acquire the abilities to analyze linear magnetically-coupled circuits and appropriately derive the network inductances and co-energy, to derive the constituitive equations of the transformer, dc machine, induction machine, and synchronous machine, to solve steady-state numerical problems, and to correctly apply reference frame theory to aid in the development of dynamic simulations.

IV. Required Background Experience

1. Knowledge of differential equations.
2. Ability to manipulate phasors and complex numbers.
3. Ability to manipulate matrices and vectors.
4. Knowledge of basic electromagnetic physics.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Course introduction and definition of electromechanical system. — 1 hr

2. Definitions of magnetic quantities: magnetic field, flux, mmf, flux density, field intensity, permeability, flux linkage, reluctance; statement of magnetism laws: Ampere's law, right hand rule, Gauss' law, Lenz's law, Lorentz forces. — 2 hrs
3. Ferromagnetic materials and their properties: magnetic moment, domain wall motion, saturation, hysteresis, eddy-currents. — 1 hr
4. Stationary magnetically-coupled circuits: Faraday's law, magnetics Ohm's law, self-inductance, mutual-inductance, transformer flux linkage and voltage equations. — 2 hrs
5. The transformer T-equivalent circuit; simulation. — 1 hr
6. Magnetic systems with mechanical motion: electromagnet, reluctance machine, windings in relative motion; total derivative of the flux linkage. — 1 hr
7. Electromechanical energy conversion: energy stored in a field, conservative fields, state functions, n-coupled coils, arbitrary displacements, relating torque to co-energy. — 3 hrs
8. Electromagnet and reluctance machine operating characteristics: operating point determination, dynamics of energy conversion, simulation. — 2 hrs
9. Analysis of dc machines: construction, commutation, armature reaction, derivation of equations, types of dc machines, steady-state characteristics. — 5 hrs
10. Problem solving for the dc machine: starting, sizing, braking, speed control. — 2 hrs
11. Simulation of dc machines; selection of time step. — 1 hr
12. Rotating mmf machines: distributed windings, air-gap mmf determination, sinusoidally-distributed windings, 1 and 2-phase rotating mmfs, P-pole devices. — 4 hrs
13. Analysis of induction machines: construction, principle of operation, winding mmfs, voltage and flux linkage operations, stator and rotor inductances, referring the rotor windings. — 3 hrs
14. Reference frame analysis of induction machines: derivation and application of matrix transformation. — 3 hrs
15. Derivation of the T-equivalent induction machine steady-state circuit: steady-state torque versus speed characteristics. — 3 hrs
16. Induction machine worked examples and simulation. — 2 hrs
17. Analysis of synchronous machines: construction, operation, winding mmfs, voltage and flux linkage equations, stator and rotor inductances, referring the rotor windings. — 2 hrs
18. Synchronous machine analysis in the rotor reference frame: Park's transformation, application of the transformation. — 2 hrs
19. Synchronous machine steady-state analysis: the rotor angle, phasor relationship. — 2 hrs

20. Synchronous machine worked examples: operating point analysis, determination of rotor angle and power factor, controlling the power factor by varying the field current. — 2 hrs

TOTAL — 44 hrs

B. Method of Instruction and Evaluation

Lectures consist of a prepared skeleton of notes that the student completes during the discussion. Homework problems and hands-on laboratory experiments reinforce the practical application of the theory presented in class. A multi-part computer tutorial is used to introduce the student to simulation and the modeling of electromechanical drive components, to provide opportunity to investigate interconnected systems, and to use high-powered tools to solve nonlinear problems. The student is graded on two midterm exams, a final exam, approximately eight graded homework assignments, four computer-based homework assignments, and five laboratory investigations.

VI. Computer Usage

Each student is required to complete a set of tutorial handouts structured to introduce the Advanced Continuous Simulation Language (ACSL) and highlight basic issues relevant to power system simulation. Computer accounts are set up on the Sparc10 workstations within the power laboratory for the students' convenience. The student may also be asked to solve nonlinear operating point problems using MATLAB.

VII. Laboratory

Working in groups of two or three, the students perform the following electromechanical device experiments and computer projects:

Hardware Experiments

1. Laboratory safety, introduction to the universal motor.	2 hrs
2. Power transformer characteristics.	2 hrs
3. Series and shunt dc machine characteristics.	2 hrs
4. Automatic starting and speed control of dc machines.	2 hrs
5. Split-phase and capacitor-start motor characteristics.	2 hrs
6. Capacitor-run motor characteristics.	2 hrs

Software Experiments

7. An introduction to the advanced continuous simulation language.	2 hrs

8.	An introduction to run-time commands and system symbols.	2 hrs
9.	An introduction to MACROS, procedures, and integration controls.	2 hrs
10.	An introduction to ACSL programming structures and I/O ACSL signal generating, integration, and bounding functions.	2 hrs
11.	Two midterm exams.	2 hrs
	TOTAL	22 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 3.5 credit hrs (70%) Design: 1.5 credit hrs (30%)

B. Design Content

Homework projects emphasize using reference frame theory and steady-state equivalent circuits to solve problems in speed control, braking, and starting for the dc machine, induction machine, and synchronous machine. An emphasis is placed on the student being able to structure a digital simulation of the various components. The laboratory experiments reinforce this endeavor by having the students derive the necessary device parameters which must be used in a numerical simulation.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Homework problems emphasize practical speed control and performance-based objectives which force the students to develop solution strategies which must oftentimes balance several counterweighing issues.

Feasibility considerations:

The problems, laboratory investigations, and simulation exercises focus on developing a bridge between analysis and practical experience. A premium is placed on whether solution results are reasonable and whether measured phenomenon corresponds to predicted results.

Development and use of modern design theory and methodology:

The students extensively use reference frame theory and various equivalent circuits to reduce nonlinear, 3-dimensional magnetics problems to manageable 1-dimensional lumped-parameter problems.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and
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Monterey, California 93943-5121

Course Coordinator: **R. W. Ashton**
Date of Outline Preparation: **2/17/95**
Prepared by: **R. W. Ashton**
Revised:

EC3150 Solid State Power Conversion (3-2)

I. Catalog Description

A detailed analytical approach is presented for the operation, performance, and control of the important types of solid state power converters found in naval shipboard power systems. The course reviews the characteristics of power semiconductor switching devices. A systems approach is used to analyze high power converters: phase controlled rectifiers, line commutated inverters, self-commutated inverters, transistor converters, and switching regulators. PREREQUISITES: EC2210 or EC2270 and electrical machine theory, or consent of instructor.

II. Text and References

Text:

Power Electronics, M. J. Fisher, PWS-Kent, Boston, 1991.

or

Power Electronics, 2nd Ed., Mohan, Undeland, and Robbins, Wiley, 1995.

References: Handouts.

III. Expected Outcomes

The student will gain an understanding of solid state inverters and converters which include several specialized types of converters of interest to the Navy. Power system harmonics and power factor are also presented. The course is designed to introduce the student to many basic power electronic circuit configurations.

IV. Required Background Experience

1. Single and three phase power.
2. ac transformers.

3. Modeling of p-n junctions, diodes, thyristors, FETs and BJTs.
4. Magnetic fields and circuits.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction and devices.		2 hrs
2. Single phase controlled rectifiers.		6 hrs
3. Three phase controlled rectifiers.		5 hrs
4. ac-to-ac phase control.		5 hrs
5. dc-to-dc converters.		6 hrs
6. Inverter including SPWM.		6 hrs
7. Exams and holidays.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

The course material is presented in lecture format. Grading is based on homework, laboratory, midterm(s), design project, and final exam.

VI. Computer Usage

The SIMULINK environment inside MATLAB will be used for modeling of dc-dc converters. The modelling will incorporate a controller and be based on the state space average technique.

VII. Laboratory

1. Single-phase half-wave controlled rectifier.		2 hrs
2. Single-phase full-wave controller rectifier.		2 hrs
3. dc load line single phase full-wave controlled rectifier.		2 hrs
4. Three-phase half-wave controlled rectifier.		2 hrs
5. Three-phase full-wave controlled rectifier.		2 hrs
6. dc load line three-phase full-wave controlled rectifier.		2 hrs
7. Single-phase ac voltage controller.	2 hrs	
8. Buck chopper.		2 hrs
9. Boost chopper.		2 hrs
10. Buck-boost chopper.		2 hrs
11. Three-phase SPWM voltage source inverter.		2 hrs
	TOTAL	22 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The class material stresses proper design of crucial power electronic circuits. The course is structured so that nearly every basic power electronic circuit analyzed in class is built and tested in the laboratory. Laboratory experiments require students to use electronic measurement techniques to structure tests to determine design limitations. Homework also stresses design practice via the choice of device characteristics for specific power needs.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Use of open ended problems:

Many homework problems have only general characteristics assigned to them. Therefore, the students must determine where to stop and how to approach and analyze results. Because of the scope of these problems, they are open ended.

Consideration of alternate solution:

Due to the variety of potential basic power electronics building blocks, a number of circuit configurations will satisfy the same needs. However, it is stressed that not all solutions provide the best alternate in PF, harmonics, cost and efficiency. The student must decide which configuration best satisfies the project goals which depend on each circuit's attributes.

Feasibility considerations:

Practically all of the circuits are discussed in class. In addition, the laboratory demonstrates the feasibility of each circuit configuration.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

This course also supports ESRs for curriculum 595 and 596 (Electronic Warfare): Electrical Engineering and Electronic Warfare.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **S. Michael**
Date of Outline Preparation: **4/28/95**
Prepared by: **S. Michael**
Revised by:

EC3200 ADVANCED ELECTRONICS ENGINEERING (3-2)

I. Catalog Description

Characteristics of differential and multistage amplifiers. Transistors frequency response, including Bipolar Junction Transistors (BJT), Junction Field Effect Transistors (JFET), and Metal Oxide Semiconductor Field Effect Transistors (MOSFET); characteristics and design consideration. Integrated circuit OPAMP applications; analysis and design of nonideal OPAMPs. Applications of BJTs and Complimentary Metal Oxide Semiconductors (CMOS) in integrated circuits, and different biasing techniques. Analysis and design of digital circuits, including Transistor Transistor Logic (TTL), Emitter Coupled Logic (ECL), and CMOS logic families. Application and design feedback amplifiers and operational amplifiers applications in analog filters and oscillators. PREREQUISITE: EC2200.

II. Text and References

Microelectronic Circuits, Sedra and Smith, Saunders College Pub., 1991.

SPICE A Guide to Circuit Simulation and Analysis Using Pspice, Prentice-Hall, 1988.

III. Expected Outcomes

Students will understand the operating characteristics of higher order models of basic electronic devices. They willapply this understanding to the analysis and design of BJT, FET, CMOS, and OPAMP analog networks, as well as to logic circuit applications. They will comprehend the frequence response characteristics of discrete transistor amplifiers. They will analyze the operational amplifier and study OPAMP applications and design.

IV. Required Background Experience

1. Understanding of basic solid state physics and semiconductor p-n junction mechanisms.

2. Applied analysis of basic diode circuits, BJTs, JFETs, and OPAMP models.
3. Familiarity of analysis and design using the above devices in different amplifier applications.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Differential amplifier and multistage amplifier.	6 hrs
2. BJT and MOS amplifier frequency response characteristics and design considerations.	8 hrs
3. Integrated circuit OPAMP applications; analysis and design of nonideal OPAMPs.	5 hrs
4. Applications of FET, MOS, and CMOS IC biasing and logic circuits.	4 hrs
5. BJT digital applications TTL and ECL logic families.	4 hrs
6. Oscillators, filters, and feedback applications.	3 hrs
7. Exams and review.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. This course will have two mid-terms plus a regularly scheduled final exam. Laboratory work constitutes 10% of the final grade.

VI. Computer Usage

Introduction to circuit simulation and device modeling using the SPICE simulation program; dc, ac, and frequency response circuit analysis using the SPICE simulation program.

VII. Laboratory

The laboratory involves measurements of FET and OPAMP parameters; analysis, design, and computer simulations of FET amplifiers, with frequency response considerations.

Most of the experiments are conducted using the Tektronix 2300 series scopes, the Tektronix 576 curve tracers, and the Tektronix TM500 Six Packs.

1. Analysis of discrete differential circuits.	2 hrs
2. Measurements of OPAMP frequency response and analysis of circuit applications.	2 hrs
3. Analysis and design of OPAMP feedback circuits.	2 hrs

4. Analysis of JFET amplifier bias technique. 2 hrs
5. Design and verification of a JFET amplifier stage to achieve assigned specifications for gain and bandwidth. 2 hrs
6. Analysis and design of a BJT amplifier stage including frequency response considerations. 2 hrs
7. Computer simulations to verify the design of the previous experiments. 4 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%)   Design: 2 credit hrs (50%)

B. Design Content

The laboratory exercises in this course involve design of different electronic circuits at the introductory level.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The laboratories require the students to design and construct electronic circuits to meet certain specifications, and then test and verify their design.

Design theory and methodology:

Students study device modelling and use circuit simulation programs (SPICE) to simulate and analyze their designs to verify that they meet the requirements according to the theory.

Use of open ended problems:

There are no unique solutions for the design problems the students are required to do, thus students are faced with open ended choices of components and circuit topologies.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. J. Pieper**
Date of Outline Preparation: **3/16/95**
Prepared by: **R. J. Pieper**
Revised:

EC3210 INTRODUCTION TO ELECTRO-OPTICAL ENGINEERING (3-1)

I. Catalog Description

An overview of the elements that comprise current electro-optical and infrared (EO/IR) military systems. Topics include radiation sources (both laser and thermal), detector devices, modulators, optical elements, and propagation characteristics. Examples of the application of the concepts taught to various military EO/IR systems, such as missile seekers, laser communications, and laser designators are discussed. PREREQUISITE: EC2210 (may be concurrent).

II. Text and References

"An Introduction to Electro-optics," notes by J. P. Powers.

III. Expected Outcomes

This course introduces students to the technology of modern optical systems including the properties of light, the principles of laser operation, the techniques of modifying the laser output, and thermal radiation in the optical portion of the spectrum.

IV. Required Background Experience

Basic electronics through linear amplifiers.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Laser light: representation, monochromaticity, beam divergence brightness, interference, coherence and polarization.	9 hrs
2. Laser principles: energy levels, transitions, absorption and gain.	6 hrs
3. Optical resonators: design and stability, propagation of	4 hrs

Gaussian beams, longitudinal and lateral modes.

4. Laser operation and design equations.	4 hrs
5. Typical laser systems.	4 hrs
6. Blackbody formulas.	3 hrs
7. Exams and holidays.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture method of instruction is used. Homework assignments, exams, and a project are counted for the final grade.

VI. Computer Usage

Recommended for three homework problems. Primarily spread-sheet and graphing programs on PC.

VII. Laboratory

Through demonstrations and short experiments the laboratories seek to introduce the student to applications, state-of-the-art equipment and supplemental topics.

1. Interference and holography demonstrations.	1 hr
2. Basic lens optics experiment.	2 hrs
3. Polarization experiment.	2 hrs
4. Lasers demonstration.	1 hr
5. Laser applications lecture.	2 hrs
6. Laser pulser experiment.	2 hrs

Equipment: HeNe laser, argon laser, Nd:YAG laser, optical power meter, polarizers, diode detector, scope pulse generator, diode laser.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Design equations for laser operation covered are rate equations and resonator mirror design.

C. Design Attribute

Formulation of design problem statement and specifications:

These equations are applied in various exercises in which system power and line width specifications need to be met. These problems, which integrate a multitude of optical considerations covered during the course, are open-ended.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

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Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R. G. Hutchins**
Date of Outline Preparation: **11/9/94**
Prepared by: **R. G. Hutchins**
Revised:

EC3310 OPTIMAL ESTIMATION: SENSOR AND DATA ASSOCIATION (3-1)

I. Catalog Description

The subject of this course is optimal estimation and Kalman filtering with extensions to sensor fusion and data association. Main topics include the theory of optimal and recursive estimation in linear (Kalman filter) and nonlinear (extended Kalman filter) systems, with applications to target tracking. Topics directly related to applications such as basic properties of sensors, target tracking models, multihypothesis data association algorithms, reduced order probabilistic models and heuristic techniques will also be discussed. Examples and projects will be drawn from radar, EW, and ASW systems. PREREQUISITES: EC2320, EC2010, MA3046.

II. Text and References

Applied Optimal Estimation, A. Gelb, MIT Press.

III. Expected Outcomes

Students will gain knowledge of estimation, sensor fusion, and data association in linear and nonlinear systems, with applications to military target tracking.

IV. Required Background Experience

1. A basic understanding of random processes, to include conditional distributions, Bayes' rule, parameter estimation, and first and second moment description of a random process.
2. State space description of dynamic systems in discrete and continuous time.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Basics of parameter estimation.	4 hrs
2.	Recursive estimation and Kalman filtering in linear systems.	9 hrs
3.	Prediction and smoothing.	4 hrs

4. Extensions to nonlinear systems and measurements. 4 hrs
5. State space models for target motion and tracking of a single target with noise. 3 hrs
6. Interactive multiple models. 5 hrs
7. Probabilistic data association for multitarget tracking. 5 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The computer projects will be individual and they all aim at the application of optimal filtering and tracking techniques in a computer simulated environment. Topics of the projects will be as follows:

1. Optimal discrete time state estimation in realistic environments.
2. Simulation and tracking of a maneuvering target.
3. Simulation of a multitarget engagement.
4. Simulation of a multitarget engagement in the presence of clutter.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (55%) Design: 1.5 credit hrs (45%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

All projects require the students to develop computer programs related to the theory developed in the lectures. Also, the students have to make educated choices between different design techniques and evaluate performances and trade-offs.

Use of open ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade off of various techniques by computer simulations.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal estimation in physical systems. For each design problem the specifications will be given in line with commonly used engineering practice.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. Cristi**
Date of Outline Preparation: **11/21/94**
Prepared by: **R. Cristi**
Revised:

EC3320 OPTIMAL CONTROL SYSTEMS (3-2)

I. Catalog Description

This course addresses the problem of designing control systems which meet given optimization criteria. The student is exposed to the development of the theory, from dynamic programming to the calculus of variation, and learns how to apply it in control engineering. PREREQUISITES: EC2300, EC2320.

II. Text and References

Optimal Control Theory: An Introduction, D. E. Kirk, Prentice-Hall, 1970.

or

Optimal Control Theory: Linear Quadratic Methods, B. D. O. Anderson and J. Moore, Prentice-Hall, 1990.

III. Expected Outcomes

Upon completion of this course students should be able to a) present the theory at the basis of advanced optimization problems, b) apply it to the design of various optimal control problems, and c) test the design by computer simulation techniques.

IV. Required Background Experience

1. State space modeling and control system design methods.
2. Classical control techniques analysis and design methods (root locus, Nyquist, frequency response).
3. Linear algebra.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Revision of state space representation of physical systems. 2 hrs

2.	Introduction to performance measures.	2 hrs
3.	Dynamic programming: the principle of optimality and its relation to optimal control systems.	6 hrs
4.	Solution to optimization problems by dynamic programming: the discrete linear regulator.	4 hrs
5.	Calculus of variations: extrema of functionals of a single function, and functionals of multiple functions.	4 hrs
6.	Application of calculus of variations to control problems: regulator, minimum time, minimum fuel control techniques.	6 hrs
7.	Frequency domain properties of linear regulators: gain margin, phase margin, time delay tolerance.	3 hrs
8.	Asymptotic properties and weight selection of the linear quadratic regulator.	3 hrs
9.	Design by combined optimal control and state estimator.	3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Laboratory work will constitute about 20% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The laboratory consists of individual computer projects and they all aim at the development of simulation techniques for physical systems of interest. In particular, the laboratory will develop the following classes of experiments:

1. Design and testing of a digital linear quadratic regulator.
2. Design and testing of a minimum time control system.
3. Design and testing of a combined linear quadratic Gaussian controller with estimated state feedback.
4. Study of sensitivity to parameter variations and robustness of optimal controllers.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student has to develop computer codes to apply techniques learned in the classroom.

Use of open ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade off of various techniques by computer simulations.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal control of physical systems. For each design problem the specifications will be given in line with commonly used engineering practice.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **M. Tummala**
Date of Outline Preparation: **2/10/95**
Prepared by: **M. Tummala**
Revised:

EC3400 Digital Signal Processing (3-1)

I. Catalog Description

The foundations of one and two-dimensional digital signal processing techniques are developed. Topics include fast Fourier transform (FFT) algorithms (1-D and 2-D), block convolution, the use of DFT and FFT to evaluate convolution (1-D and 2-D), elements of multirate signal processing and rate conversion, and design methods for 1-D nonrecursive and recursive digital filters. Computer-aided design techniques are emphasized. Introduction to time-frequency representation through the short-time Fourier transform and wavelet transforms. The algorithms introduced have direct applications in sonar and radar signal processing, IR sensor arrays, modern navy weapon systems, and also in voice and data communications. PREREQUISITE: EC2410.

II. Text and References

Texts:

Digital Signal Processing: Principles, Algorithms, and Applications, 2nd Ed., J.G. Proakis and D. Manolakis, Macmillan, 1992.

"Two-Dimensional Signal Processing," Notes.

"Linear and Quadratic Time-Frequency Signal Representations," F Hlawatsch and G. F. Boudreaux-Bartels, *IEEE Signal Processing Magazine*, Vol. 9, pp. 21-67, April 1992.

"Wavelets and Signal Processing," O. Rioul and M. Vetterli, *IEEE Signal Processing Magazine*, Vol. 8, pp. 14-38, October 1991.

References:

Multidimensional Digital Signal Processing, D.E. Dudgeon and R.M. Mersereau, Prentice-Hall, 1984.

Discrete-time Signal Processing, A.V. Oppenheim and R. W. Schafer, Prentice-Hall, 1989
Digital Signal Processing: A Practical Approach, E.C. Ifeachor and B.W. Jervis, Addison-Wesley, 1993.

Multirate Systems and Filter Banks, P. P. Vaidyanathan, Prentice-Hall, 1993.

III. Expected Outcomes

Students develop the capability to design 1-D digital filters to meet specific performance criteria and to understand the basics of two-dimensional (2-D) signals and systems. They learn to use the fast Fourier transform algorithm to compute the DFT in 1-D and 2-D and to apply FFT to implement finite impulse response filters using block convolution techniques (1-D and 2-D) . The student also gains an introduction to some advanced topics, such as multirate signal processing, the short-time Fourier transform, and wavelet transforms.

IV. Required Background Experience

1. Linear difference equations.
2. Frequency response of discrete systems.
3. Two-sided (bilateral) z-transforms and their inverses.
4. System response using convolution and/or z-transforms.
5. Cascade and parallel realizations of discrete systems.
6. Discrete Fourier transform and discrete Fourier series.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review: z-transforms, convolution, frequency response, and DFT.	3 hrs
2. Fast Fourier transform: summary of decimation in time FFT algorithm (radix 2), inverse FFT, fast convolution using FFT.	3 hrs
3. Finite impulse response filters: linear and zero-phase realizations, windowing, design techniques, frequency sampling, design by inverse DFT.	3 hrs
4. Infinite impulse response filters: properties of IIR filters, analog filter design and frequency transformations, design of digital filters from analog filters, and direct digital design techniques.	4 hrs
5. Two-dimensional signals and systems: 2-D signals (rectangular sampling only), 2-D systems, impulse response,	4 hrs

system response, stability. 2-D Fourier transform and DFT, vector radix FFT.

6. Two-D filtering: FIR filtering. overlap-add method for implementation. IIR filtering, recursive computability. FIR filter design (optional). — 4 hrs
7. Introduction to multirate filtering: sampling rate conversion, decimation, interpolation. — 3 hrs
8. Short-time Fourier transform: time-frequency analysis of signals, short-time Fourier transform, time-frequency uncertainty principle. — 3 hrs
9. Introduction to wavelet transform: multiresolution analysis of signals, continuous wavelet transform. — 3 hrs
10. Exams and holidays. — 3 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

Instruction consists of lectures and computer demonstrations. Computer assignments are used to supplement the classroom lectures. The lecture material is tested using at least one midterm exam and a final exam. Computer projects typically account for 30% of the final grade.

VI. Computer Usage

Computer demonstrations are used in the classroom to present the digital filter design and analysis. Computer projects utilizing MATLAB or C are assigned:

1. FFT and linear convolution.
2. FIR filter design.
3. IIR filter design.
4. 2-D FFT and linear convolution.
5. Design of sample rate converters (non-integer case).
6. Short-time Fourier transform.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer projects assigned in this course involve design of FIR and IIR digital filters (lowpass, highpass, bandpass, and notch) based on analog design and direct digital design approaches. Design of simple sample rate converters and the use of the FFT algorithm to implement FIR filters is also included.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Design of sample rate converters (particularly the non-integer rate conversion) requires considerable creativity on the part of the student.

Use of open ended problems:

Design of digital filters is an open ended problem. Students are encouraged to explore advanced methods of filter design with the goal being either sharp magnitude response or linear phase response.

Development and use of modern design theory and methodology:

The course material is continuously updated to include modern methods of digital filter design. The design techniques covered in the course are contemporary and students are required to use them in their filter design projects.

Realistic constraints on design:

In their design projects, students learn the design trade-off between the filter order and the sharpness of the magnitude response; filter order, linear phase response, and the sharpness of the magnitude response (FIR case); flatness of the magnitude response and its sharpness.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **2/1/95**
Prepared by: **C. W. Therrien**
Revised:

EC3410 DISCRETE-TIME RANDOM SIGNALS (4-0)

I. Catalog Description

Fundamentals of discrete-time random processes are developed from a probabilistic and statistical point of view for digital signal processing, control, and communications. Topics covered are random vectors and description of discrete-time random signals, sampling of continuous-time random signals, statistical averages and second moment analysis, linear transformations, and fundamentals of estimation theory. Subject matter also includes FIR optimal (Wiener) filtering, and an introduction to linear prediction. PREREQUISITES: EC2410 (may be concurrent), EC2010, and MA3046.

II. Text and References

Descrete Random Signals and Statistical Signal Processing, C. W. Therrien, Prentice-Hall, 1992.

III. Expected Outcomes

Knowledge of fundamental principles related to the analysis of discrete-time random signals. Ability to apply basic mathematical tools and methods for the engineering analysis of random signals. Minimum essential requirements for more advanced course work in optimal signal processing, speech, image processing, spectral analysis, array processing, and stochastic control.

IV. Required Background Experience

Analysis of one-dimensional (1-D) linear time-invariant descrete signal processing systems for deterministic signals:

1. Difference equations.
2. Convolution.
3. Frequency (Fourier) analysis.
4. Bilateral z-transforms.
5. Probability and random variables.
6. Basic linear algebra.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction, random vectors, distribution and density functions, moments, transformations, decorrelation via eigenvector and triangular decomposition.	8 hrs
2. Random processes, Bernoulli, random walk, Markov, Gaussian, others.	8 hrs
3. Second moment analysis in time, frequency, and z domains, periodic processes, continuous processes, white noise.	4 hrs
4. Transformations by linear systems, matched filter, spectral factorization.	8 hrs
5. Maximum likelihood estimation, estimating moments, Bayes estimation of random variables, linear mean-square estimation, classical methods of spectrum estimation.	6 hrs
6. Orthogonality principle, linear prediction, FIR Wiener filter, Wold decomposition.	8 hrs
7. Exams and holidays.	4 hrs
TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture/recitation method of instruction is used. There are two midterm exams and a final exam. Completion of homework and computer assignments is counted as part of the final grade.

VI. Computer Usage

Regular computer assignments that explore the analysis of signals and data on the computer. Use of MATLAB or APL is recommended for completion of these assignments.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (100%)

B. Design Content

None

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **2/1/95**
Prepared by: **C. W. Therrien**
Revised:

EC3420 STATISTICAL DIGITAL SIGNAL PROCESSING (3-1)

I. Catalog Description

Modern naval systems are highly dependent on advanced statistical signal processing techniques. Modern methods of digital signal processing are developed in this course from a statistical point of view. Methods are developed for processing random signals through statistical data analysis and modeling. Topics include the IIR Wiener filter and the scalar form of the Kalman filter, linear prediction, MA, AR, and ARMA signal modeling, lattice structures, and an introduction to modern methods of spectrum estimation. PREREQUISITE: EC3410.

II. Text and References

Discrete Random Signals and Statistical Signal Processing, C. W. Therrien, Prentice Hall, 1992.

IV. Required Background Experience

1. Analysis of one-dimensional (1-D) deterministic and random sequences and discrete linear systems including difference equations, convolution, frequency and z-transform analysis.
2. Principles of estimation theory for parameters and random variables.
3. Linear algebra.
4. Ability to write programs in a high level or very high level language.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of FIR Wiener filtering for discrete random sequences.	3 hrs
2. IIR Wiener filter, scalar Kalman filter.	6 hrs
3. Linear prediction forward and backward linear prediction, autoregressive models, Levinson and Schur algorithms, lattice filters.	6 hrs
4. Least squares methods of signal modeling, autocorrelation, covariance, and Burg's method of linear prediction, ARMA	6 hrs

modeling, Prony's method and other techniques.

5. Modern (model-based) methods of spectrum estimation, autoregressive and maximum entropy methods, maximum likelihood (minimum variance) method, signal and noise subspace-based methods. — 9 hrs
6. Exams, review, and miscellaneous. — 3 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture/recitation method of instruction is used. There is one midterm and a final exam. Computer assignments count a significant amount (up to 35%) of the final grade. Completion of other homework is also required.

VI. Computer Usage

Computer-based assignments in design and application of algorithms for data analysis and signal modeling. These assignments emphasize the strong role of the computer in modern digital signal processing.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

Students are asked to design statistically optimal filters, to develop models for measured data, and to implement and compare alternative approaches to spectrum estimation.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Use of open ended problems:

Students are asked to implement their own signal processing algorithms based on principles learned in class. The problem is open ended because the student must turn a set of equations into computer code. Many times the computational procedure is not explicit in the equations. For example, students may have to decide upon the form of a statistical estimate to replace a theoretical quantity.

Consideration of alternate solutions:

In problems of filtering, prediction, and signal modeling, students design digital filters to minimize a criterion of optimality (usually mean-square error) for particular sets of data provided to them. They learn that there are trade-offs in the selection of parameters or the algorithm selected for the design; for example, whether to use an FIR or an IIR filter, whether the IIR filter will have both poles and zeros or only poles, and other similar considerations. In spectrum estimation students learn many approaches, both parametric and nonparametric. They are given some various classes of data, asked to implement the algorithms, choose their own parameters, and recommend a specific algorithm and a specific implementation of the algorithm (including values for all of the parameters) to be used for a particular class of data.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **L. J. Ziomek**
Date of Outline Preparation: **2/21/95**
Prepared by: **L. J. Ziomek**
Revised:

EC3450 FUNDAMENTALS OF OCEAN ACOUSTICS (4-0)

I. Catalog Description

Introduction to various mathematical techniques (both exact and approximate) special functions (e.g., Bessel functions, Hankel functions, and Legendre polynomials), orthogonality relationships, etc., that are used to model and solve real world problems concerning the propagation of sound in the ocean. Topics include, for example, reflection and transmission coefficients, ocean waveguide pulse-propagation models based on normal mode and full-wave theory, the WKB approximation, three-dimensional ray acoustics, and the parabolic equation approximation. PREREQUISITES: Undergraduate calculus and physics.

II. Text and References

Fundamentals of Acoustic Field Theory and Space-Time Signal Processing, L. J. Ziomek, CRC Press, Inc., 1995.

III. Expected Outcomes

Knowledge of various mathematical techniques (both exact and approximate) that can be used to model and solve real world problems involving the propagation of sound in the ocean medium.

IV. Required Background Experience

1. Standard undergraduate sequence of calculus and physics courses.
2. Proficiency in complex arithmetic.
3. Knowledge of Fourier transform theory.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Time-average intensity vector and time-average power.	0.5 hr
2. Sound-pressure level, source level, transmission loss, and sound-intensity level.	0.5 hr

3.	Solution of the linear three-dimensional homogeneous wave equation in the rectangular coordinate system.	1 hr
4.	Free-space propagation: time-harmonic solution of the homogeneous wave equation; group speeds, phase speeds, and wavelengths; solution of the homogeneous wave equation for arbitrary time dependence.	3 hrs
5.	Reflection and transmission coefficients.	4 hrs
6.	The time-independent free-space Green's function: solution of the homogeneous and inhomogeneous Helmholtz equations.	1 hr
7.	Solution of the linear three-dimensional inhomogeneous wave equation with arbitrary source distribution: free-space solution.	2 hrs
8.	Integral representations of the time-independent free-space Green's function in rectangular coordinates.	1 hr
9.	Solution of the linear three-dimensional homogeneous wave equation in the cylindrical coordinate system.	1.5 hrs
10.	Integral representations of the time-independent free-space Green's function in cylindrical coordinates.	1 hr
11.	Waveguide models of the ocean -- normal modes: pressure-release surface with a rigid bottom; pressure-release surface with a fluid bottom.	4 hrs
12.	Waveguide model of the ocean -- full-wave solution.	3 hrs
13.	Solution of the linear three-dimensional homogeneous wave equation in the spherical coordinate system.	2 hrs
14.	Free-space propagation: radiation from a vibrating sphere; monopole and dipole modes of vibration.	2 hrs
15.	The WKB approximation.	2 hrs
16.	Ray acoustics: transport and eikonal equations; solution of the eikonal equation; ray equations; amplitude calculations along rays-solution of the transport equation; acoustic pressure calculations for depth-dependent speeds of sound valid at turning points and focal points.	9 hrs
17.	The parabolic equation approximation.	2.5 hrs
18.	Holidays and exams.	4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There are two one-hour exams and a final exam.

VI. Computer Usage

None

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (100%)

B. Design Content

None

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **A. W. Lam**
Date of Outline Preparation: **2/6/95**
Prepared by: **A. W. Lam**
Revised:

EC3500 ANALYSIS OF RANDOM SIGNALS (4-0)

I. Catalog Description

Fundamental concepts and useful tools for analyzing non-deterministic signals and noise in military communication, control, and signal processing systems are developed. Topics include properties of random processes, correlation functions, energy and spectral densities, linear systems and mean square estimation, noise models and special processes. PREREQUISITES: EC2500 (may be concurrent) and EC2010, or consent of instructor.

II. Text and References

Probability, Random Variables, and Stochastic Processes, A. Papoulis, 3rd ed., McGraw-Hill, 1991.

III. Expected Outcomes

An understanding of random processes sufficient for graduate work in communications, control, computer, and signal processing systems.

IV. Required Background Experience

Elementary probability and statistics, concepts of random variables, probability density and distribution functions, and joint descriptions of multiple random variables; a first course in electrical communications.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of probability and random variables: Probability space, axioms of probability, independent events, conditional probability, law of order probability, Bayes' formula, random variables, distribution and density functions, expectations, functions of random variables, second order joint moments, the law of large numbers, central limit theorem. 2 hrs

2. Random processes: definitions, stationary processes, systems with stochastic inputs, ergodicity, correlations and spectra.		12 hrs
3. Applications: random walk, Brownian motion, thermal noise, Poisson counting and point processes, shot noise, modulation, bandlimited processes and sampling theory, cyclostationary processes, matched filters, BPSK, ALOHA protocol, M/M/1 queue, optical communications.		14 hrs
4. Mean square estimation: the orthogonality principle, filtering and prediction, Wiener filters, Kalman filters.		13 hrs
5. Exams and holidays.		3 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam.

VI. Computer Usage

Homework and/or projects will be assigned that utilize MATLAB.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (100%)

B. Design Content

None

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R.C. Robertson**
Date of Outline Preparation: **2/7/95**
Prepared by: **R. C. Robertson**
Revised:

EC 3510 COMMUNICATIONS ENGINEERING (3-1)

I. Catalog Description

The influence of noise and interference on the design and selection of hardware in practical communication transmitters and receivers is analyzed. Specific topics include link budget analysis and signal-to-noise ratio calculations, receiver noise performance for various modulation schemes, bandwidth trade-offs, and hardware parameters. Examples of military communications systems are included. PREREQUISITES: EC2220 and EC3500.

II. Text and References

Digital and Analog Communications Systems, 4th Ed., Couch, Macmillan, 1993

or

Digital Communications, Fundamentals and Applications, Bernard Sklar, PTR Prentice-Hall, 1988.

or

Communications Systems Engineering, J. G. Proakis and M. Salehi, Prentice-Hall, 1994.

III. Expected outcomes

A knowledge of the capabilities and limitations of analog and digital communication systems.

IV. Required Background Experience

1. Fourier analysis and the relationship between the time-domain and frequency-domain.
2. Random variables and random processes; autocorrelation functions, power spectral density, narrow-band random processes.

3. Conventional analog communication systems (AM, DSBSC-AM, SSB-AM, FM).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Link budget analysis.	4 hrs
2. Effect of noise on AM, DSBSC-AM, SSB-AM receivers.	3 hrs
3. Effect of noise on FM and PM receivers, FM threshold, threshold extension using PLL and FM with feedback, pre-emphasis and de-emphasis.	5 hrs
4. Binary digital communications: BPSK, ASK, BFSK, DPSK, baseband and passband waveforms, transmission bandwidth, and baseband line codes.	4 hrs
5. Coherent demodulators for binary signaling and performance in AWGN.	3 hrs
6. Noncoherent demodulators for binary signaling and performance in AWGN.	3 hrs
7. Intersymbol interference.	2 hrs
8. Bandwidth efficient digital communications: CPFSK, QPSK, OQPSK, and MSK waveforms, transmission bandwidth, receiver structure, performance in AWGN, comparison with binary signaling schemes.	4 hrs
9. Carrier and symbol synchronization: Costas loops, open loop symbol synchronizers, delay-locked loops.	3 hrs
10. Exams and holidays.	2 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam.

VI. Computer Usage

Homework and/or projects are assigned that utilize MATLAB and/or the SPC toolbox.

VII. Laboratory

Working in groups of two, the students are asked to design, build, and test:

1. A circuit to generate a BFSK signal.
2. A circuit to demodulate the BFSK signal generated in 1.

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

Students learn how to design a communication link and how to design a binary digital commuication system given the inherent trade offs in power, bandwidth, bit rate, and performance.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student must learn how to modify various aspects of a communication link design to achieve required power and noise temperature specifications.

Consideration of alternate solutions:

Students must learn how to select a binary digital communication system for a specific application such that power, bandwidth, bit rate, and performance criteria are satisfied.

IX. Educational Skills Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **J. P. Powers**
Date of Outline Preparation: **2/23/95**
Prepared by: **J. P. Powers**
Revised:

EC3550 FIBER OPTIC SYSTEMS (3-1)

I. Catalog Description

An introduction to the components and to the concepts of designing fiber optic communications systems for military applications. Includes fiber properties and parameters, fiber fabrication and testing, LED and injection laser sources, pin photodiodes and avalanche photodiode detectors, receiver design considerations, connector and splice techniques, and system design incorporating analysis and trade offs. Data distribution techniques are also studied. PREREQUISITES: EC2220 and EC2600.

II. Texts and References

Introduction to Fiber Optic Systems, J. P. Powers, Aksen Associates/Irwin, June 1993.

III. Expected Outcomes

To acquire an understanding of the components in a fiber optic communications link in sufficient detail that a link could be designed, built and successfully tested. To acquire the ability to analyze given link or synthesize a desired link.

IV. Required Background Experience

Knowledge in the use and application of electronic amplifiers, comparators, op-amps, waveguides, and modes.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction: advantages and disadvantages of fibers.	2 hrs
2. Fiber types: step index and graded index, multimode. and single mode.	2 hrs
3. Fiber parameters: numerical aperture, losses, pulse spreading.	4 hrs

4. Sources: LEDs and injection lasers.		4 hrs
5. Detectors: PIN diodes and avalanche photodiodes, noise, signal-to-noise.		3 hrs
6. Receivers: preamplifiers, equalizer.		2 hrs
7. Connectors: alignment requirements, geometries.		2 hrs
8. Splices: techniques, losses.		2 hrs
9. System design: system margin.		2 hrs
10. System design: trade-off analysis.		3 hrs
11. Data bus applications: tees, stars, FDDI, SONET.		3 hrs
12. Exams and review.		4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Lectures, laboratories, and out-of-class work. Evaluation is by written exams.

VI. Computer Usage

Students are encouraged to solve homework and link margin calculations with spreadsheets or other math programs on PCs. Some problems require computer solutions.

VII. Laboratory

The laboratory meets every two weeks for a two-hour period. The lab is available to student lab groups (two per group) during a two-hour period on a sign-up basis. The experiments are:

1. Fiber parameter measurements and OTDR devices.
2. Fiber connectors and losses.
3. Optical source characterization.
4. Analog and digital links.
5. Digital link performance.

Equipment required consists of scopes, OTDR, diode laser, LEDs, stabilized power supply, bit error rate counter, HeNe laser, optical signal generator, optical loss meter, pin diode detector.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Design links to meet specifications. Students are also required to design a methodology for predicting the minimum wavelength for dispersion and test the methodology using computer simulations.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The dispersion minimization problem requires student creativity and no two solutions are exactly the same.

Use of open ended problems:

In the application of link design theory students are required to predict optical fiber component parameters which meet communication system specifications. These exercises are open ended.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **M. A. Morgan**
Date of Outline Preparation: **2/22/95**
Prepared by: **M. A. Morgan**
Revised:

EC3600 ELECTROMAGNETIC RADIATION, SCATTERING AND PROPAGATION (3-2)

I. Catalog Description

The principles of electromagnetic radiation are applied to antenna engineering, scattering, and propagation. The characteristics of various practical antenna types are considered including arrays and reflectors. Scattering concepts are introduced and propagation phenomena are considered. Applications include sidelobe suppression, radar target scattering and stealth approaches, HF and satellite communications. PREREQUISITE: EC2610 or equivalent.

II. Text and References

Antennas and Radiowave Propagation, R. E. Collin, McGraw-Hill, 1989.

or

Antenna Theory and Design, Stutzman and Thiele, Wiley, 1981.

III. Expected Outcomes

An understanding is expected to be developed of the electromagnetic and system characteristics of antennas, scatterers and the propagation channel as well as a working knowledge of the engineering methods which may be used to calculate these characteristics.

IV. Required Background Experience

1. Working knowledge of vector calculus and basic coordinate systems.
2. Electrostatic and magnetostatic field theory.
3. Fundamentals of time-harmonic electromagnetic field theory.
4. Concepts of plane wave propagation including polariization and power flow.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Review of electromagnetics, plane waves, and polarization.	2 hrs
2.	Elemental sources, dipole and monopole antennas.	3 hrs
3.	Antenna fundamentals: gain, pattern, effective length and aperture, reciprocity, antenna temperature.	4 hrs
4.	Array theory, phased and adaptive arrays.	3 hrs
5.	Broadband antennas.	2 hrs
6.	Integral equations and moment method numerical solutions.	3 hrs
7.	Aperture antennas and horns.	3 hrs
8.	Reflector antennas.	2 hrs
9.	Scattering cross-section.	3 hrs
10.	Tropospheric and ionospheric propagation principles.	5 hrs
11.	Exams and holidays.	3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. Graded homework forms 10% of the grade, two midterm exams form 40% of the grade, the final exam forms 30% of the grade, a term project provides 10% of the grade, and graded laboratory exercises form the remaining 10% of the grade.

VI. Computer Usage

Computer exercises include the evaluation and design of antenna arrays, horn antennas, reflector antennas, communication systems, and the moment method solution of the thin-wire Hallen's integral equation. Software such as WIRE, AWAS, and MININEC are used for wire antenna modeling. MATLAB or other high level programming language is used for design and analysis problems.

VII. Laboratory

The goals of the laboratory exercises are to convey a physical understanding of abstract concepts and to acquaint the student with the devices and methodology incorporated in electromagnetic measurements. Major equipment items are indicated in parentheses.

1.	Dipole antenna patterns (FM receiver, servo-controlled antenna mast, antenna pattern turntable dipile and other VHF antennas).	2 hrs
2.	Antenna channel transmission loss (modulated mm wave receiver reflector antennas, detector with power meter).	2 hrs
3.	Monopole impedance measurements (VHF signal generator, vector voltmeter).	2 hrs
4.	Two-element phased array (FM receiver, Servo-controlled antenna most antenna pattern turnable, adjustable two-element VHF array).	2 hrs

5. Antenna analysis computer codes (IBM personal computers, software packages: AF, AP, wire mininec) IBM compatible. — 2 hrs
6. Microwave horn and reflector patterns (X-band oscillator, servo-controlled antenna pedestal, microwave receiver, and pen plotter). — 2 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

Homework, exams, laboratory exercises, and the term project involve evaluation and design of optimal array, horn, and reflector antennas to meet established specifications. Extensive evaluation and design related issues are also covered in considering propagation channels and communication systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students perform creative designs of several types of antennas and conduct individual analyses of communication system performance.

Formulation of design problem statement and specifications:

Students are introduced to the tradeoffs between antenna performance specifications and design criteria, including antenna types and physical parameters required. The role of antennas and other considerations in communication systems are also covered, with student participation in relating specifications to design parameters.

Feasibility considerations and realistic constraints on design:

Students are given examples of impossible antenna design specifications. They are also made aware of physical limits to supergain phenomena.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Monterey, California 93943-5121

Course Coordinator: **J. B. Knorr**
Date of Outline Preparation: **2/18/95**
Prepared by: **J. B. Knorr**
Revised by:

EC3610 MICROWAVE ENGINEERING (3-2)

I. Catalog Description

This course provides an overview of the circuits and devices used in microwave radar communication and electronic warfare systems. The course covers network analysis using scattering parameters, transmission media, selected circuits, electron tubes, solid state devices, and monolithic integrated circuits. Circuits and devices are studied in the laboratory using both hardware and computer simulation. PREREQUISITE: EC2610.

II. Text and References

Microwave Engineering, 1st Ed., D. M. Pozar, Addison-Wesley, 1990.

Microwave Devices and Circuits, 3rd Ed., S.Y. Liao, Prentice-Hall, 1990.

III. Expected Outcomes

After completing this course the students should know techniques for analysis and design of microwave circuits and devices and the application of these elements as microwave system building blocks in areas such as communications, radar, and electronic warfare.

IV. Required Background Experience

1. Maxwell's equations.
2. Plane waves.
3. Transmission line theory.
4. Waveguide theory.
5. Cavity resonator theory.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction, network analysis using S-parameters. 3 hrs

2. Strip transmission lines.		3 hrs
3. Discontinuities and models.		2 hrs
4. TEM line couplers.		2 hrs
5. Coupled line filters.		2 hrs
6. TEDs, Schottky diodes and applications.		3 hrs
7. GaAs FETs and applications.		3 hrs
8. Monolithic microwave integrated circuits.		3 hrs
9. Klystrons.		3 hrs
10. Traveling wave tubes.		3 hrs
11. Magnetrons.		3 hrs
12. Exams and holidays.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory method of instruction is used. Students knowledge is evaluated on the basis of two mid-term exams, a final exam, and laboratory work. Laboratory work includes a design project.

VI. Computer Usage

Students use a microwave design workstation to simulate various circuits and to determine performance.

VII. Laboratory

Students use scalar and vector network analyzers, spectrum analyzers, a microwave probe station, and a microwave design workstation. Lab exercises involving a variety of tube and solid state devices are conducted, and students must complete a design project.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Students are asked to design microwave circuits in homework problems and in a laboratory project. A microwave design workstation is utilized.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are free to be innovative in choosing a project and achieving a solution.

Use of open ended problems:

Each student is asked to design a microwave circuit and must decide what to design, what must be specified, what transmission medium to use, and how the design is to be carried out. Students generally arrive at a solution iteratively on the basis of meetings with the instructor.

Development and use of modern design theory and methodology:

Students employ mathematical design approaches and use a microwave design workstation.

Formulation of design problem statement and specifications:

Students must generate design specifications for the project they choose to pursue.

Alternate solutions:

Students must consider realization using different transmission media.

Feasibility:

Students must design a circuit which can be fabricated.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Naval Postgraduate School
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Course Coordinator: **J. B. Knorr**
Date of Outline Preparation: **2/8/95**
Prepared by: **J. B. Knorr**
Revised:

EC3630 RADIOWAVE PROPAGATION (3-0)

I. Catalog Description

This course treats the effects of the earth and its atmosphere on electromagnetic waves in the frequency range up to about 300 GHz. Topics covered include ground waves, sky waves, meteor burst, scatter, ducting reflection, refraction, diffraction, attenuation, and fading. Basic theory is covered and computer models are introduced where appropriate. Emphasis is placed on determination of the transmission loss between transmitting and receiving antennas. Antenna parameters are covered briefly. PREREQUISITES: EC2610 or equivalent.

II. Text and References

Instructor's notes

Radio Wave Propagation and Antennas, Griffiths, Prentice Hall, 1987.

III. Expected Outcomes

After completing this course the student should have the knowledge required to determine the propagation factors which are applicable in various situations and to calculate the associated losses. An understanding of the limitations placed on system performance will also be developed.

IV. Required Background Experience

1. Transmission lines and waveguides (EC2610).
2. Antenna engineering (desirable but not necessary).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Ground waves.	6 hrs
2. Sky waves.	9 hrs
3. Meteor burst.	3 hrs

4. Scatter.		3 hrs
5. Reflection.		2 hrs
6. Refraction and ducting.		4 hrs
7. Diffraction.		2 hrs
8. Attenuation.		2 hrs
9. Multipath and fading.		2 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture method of instruction is used. Student knowledge is evaluated on the basis of hand-in problems, mid-term exams, and a final exam.

VI. Computer Usage

Students use available propagation codes such as MINIMUF, PROPHET, and DUCT on workstations or personal computers to solve homework assignments involving the investigation of propagation effects.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (100%)

B. Design Content

None

C. Design Attributes

None

IX. Educational Skills Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **R. W. Adler**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. W. Adler**
Revised:

EC3650 COMPUTATIONAL ELECTROMAGNETIC MODELING TECHNIQUES (4-1)

I. Catalog Description

This is a ``hands-on'' course on numerical solution of static, time-harmonic, and transient electromagnetic field problems of the type encountered in radar and electronic warfare. One numerical technique for each of the two broad categories of integral and differential techniques is taught: Method of Moments (MOM) for static and time-harmonic field problems and Finite Differences (FD) for static, time-harmonic, and transient electromagnetic field problems. Applications include planar transmission lines, radiation and scattering by thin wires, waveguide and cavity modes, and transient scattering by perfectly conducting objects of simple shape. Students write their own computer codes to implement the techniques taught in class, using a high-level programming environment such as MATLAB or MATHCAD. Commercial and "in-house" numerical electromagnetic codes are introduced in the laboratory. PREREQUISITE: EC3600 or consent of instructor.

II. Text and References

Techniques in Numerical Electromagnetics, R. Sadiku, CRC Press, 1993

III. Expected Outcomes

The course main objective is to enable students to write their own electromagnetic codes for solving realistic static, time-harmonic, and transient electromagnetic field problems that are encountered in radar and electronic warfare. The three specific objectives are: understanding of computer implementation of fundamental laws of electromagnetics, efficient use of high-level programming environments for problem solution and visualization of results, and interpretation and validation of computer-generated results.

IV. Required Background Experience

1. Maxwell's equations in integral and differential form and boundary conditions.
2. Scalar and vector potentials and superposition integrals.
3. Basic matrix algebra and programming concepts.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Review of electromagnetic theory fundamentals.	4 hrs
2.	Superposition integral and Method of Moments (MOM) in electrostatics.	3 hrs
3.	Finite Differences (FD) in electrostatics.	3 hrs
4.	MOM for time-harmonic fields - radiation and scattering by thin wires.	4 hrs
5.	MOM codes (MININEC/ELNEC/NEC) and their limitations.	4 hrs
6.	FD's for time-harmonic fields (interior boundary value problems).	4 hrs
7.	Field-network analogues.	4 hrs
8.	Fundamentals of Finite Differences - Time Domain (FDTD).	4 hrs
9.	Open boundary simulation.	4 hrs
10.	Sub-cellular extension and transient radiation by wires.	4 hrs
11.	Scattering by perfectly conducting objects of simple shape.	3 hrs
12.	Exams and holidays.	3 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There is one midterm exam given. The term projects are used in place of a final exam. Laboratory work, independent of demonstrations, constitutes about 3 hours per week and contributes 25% of the final grade. The term projects(s) constitute about 50% of the final grade.

VI. Computer Usage

Personal computers and/or workstations are the primary "tools" used in the course. Their use is twofold: for students to develop their own codes using a programming environment of their choice, and for students to learn to use available computational electromagnetic software. The primary software for student program development are mathematical packages such as MATLAB and Mathcad and a word processor with scientific equation capability. Commercially available electromagnetic codes such as ELNEC are used for verification of student's results.

VII. Laboratory

All laboratory exercises are computer-based. Laboratory sessions address numerical techniques and their implementation in a particular program and "experimentation" with the software.

Lab 1:	MATLAB FD program for 2D electrostatic and magnetostatic problems.	2 hrs
Lab 2:	Mathcad MOM implementation for charged wires.	2 hrs
Lab 3:	Mathcad MOM implementation for wire radiation and scattering.	2 hrs
Lab 4:	ELNEC and MININEC MOM codes.	2 hrs
Lab 5:	NEC MOM code examples.	3 hrs
	TOTAL	11 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%)   Design: 2 credit hrs (45%)

B. Design Content

The laboratory exercises are designed to demonstrate software tools that can be used by each student to develop codes to solve EM scattering and radiation problems. The problems are simple in nature but have direct application to real-world military systems.

C. Design Attribute

Development of student creativity:

Each student is responsible for the development of a code associated with the EM performance of a scattering or radiation structure. The efficient implementation of their algorithm depends on their creativity in the use of the MATLAB or MATHCAD software. This experience provides a valuable lesson for use in following project-oriented coursework. The requirement to validate their codes via comparison to solutions obtained from commercial proven codes adds the incentive to excel in the tasks and to show relative value of the student-developed programs.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **J. B. Knorr**
Date of Outline Preparation: **3/16/95**
Prepared by: **J. B. Knorr**
Revised:

EC3670 PRINCIPLES OF RADAR SYSTEMS (4-2)

I. Catalog Description

For students in the Avionics curriculum. Topics include microwave devices, microwave propagation, antenna fundamentals, electronically steerable arrays, pulse radar basics, detection of signals in noise, the radar equation, CW, pulse doppler, moving-target indicators, pulse compression, the ambiguity function, tracking radars, conical scan, track-while-scan, scan with compensation and monopulse. PREREQUISITES: EC2612, EC3402, EC3602, and SECRET clearance.

II. Text and References

Text:

Introduction to Radar Systems, 2nd Ed., Skolnik, McGraw-Hill, 1980.

Reference:

Principles of Modern Radar, Eaves & Reedy, Van Nostrand, Reinhold, 1987.

III. Expected Outcomes

The student will be prepared for analysis and design of radar systems through a study of (a) types of radar systems, (b) signal noise and clutter waveforms, (c) the receiver, antenna, and transmitter subsystems, (d) the microwave components and devices, (e) the propagation channel, and (f) target characteristics.

IV. Required Background Experience

1. Electromagnetic engineering.
2. Antennas.
3. Signal processing.
4. U.S. citizenship.
5. SECRET clearance.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. The radar equation.		5 hrs
2. CW and FM radar.		3 hrs
3. MTI and pulse Doppler radar.		5 hrs
4. Tracking radar.		3 hrs
5. Staggered PRF's - double cancellation; subclutter.		4 hrs
6. Receivers and signal detection.		4 hrs
7. Waveform design.		4 hrs
8. Propagation.		4 hrs
9. Clutter.		4 hrs
10. Advanced topics.		4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory method of instruction is used. Student knowledge is evaluated on the basis of mid-term exams and a final exam.

VI. Computer Usage

Students are introduced to the computer program RGCALC.

VII. Laboratory

1. Radar systems: SPS-10, SPS-40, UPS-1, MK-25.
2. Instruments: general purpose test instruments, spectrum analyzer, power meter, noise figure meter, convertor, signal generator, chart recorder.
3. Components: couplers, attenuators, matched loads.
4. Experiments:
   a. Basic radar measurements (SPS-10 radar).
   b. Subclutter visibility demonstration (UPS-1).
   c. Pulse compression (SPS-40A).
   d. Radar X-section demonstration (Mark 25 tracking radar).
   e. Wave propagation experiment.

VIII. Accreditation

A. Science/Design Mix

Science: 4 credit hrs (80%) Design: 1 credit hr (20%)

B. Design Content

Some aspects of radar system design are covered in assigned homework problems.

C. Design Attribute

Development and use of modern design theory and methodology:

Students use theory covered in classroom lectures and computer software to solve homework problems with design content.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for the Aeronautical Engineering (Avionics) curriculum (611):

Electrical Engineering:

Understand basic electrical circuits, systems, electronic devices, microwave communications, signal processing, antenna theory, electro-optics of pulse and continuous wave radars, electrical apertures, conformal arrays, adaptive beamforming, and infrared and laser technology as foundational tools for application to design and analysis of military aircraft avionics systems.

Naval Postgraduate School
Department of Electrical and Computer Engineering
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Course Coordinator: **J. T. Butler**
Date of Outline Preparation: **3/16/95**
Prepared by: **J. T. Butler**
Revised:

EC 3800 MICROPROCESSOR BASED SYSTEM DESIGN (3-2)

I. Catalog Description

Advanced microprocessor system concepts are studied. Microprocessor systems are widely used for embedded control in military systems as well as for stand-alone computers. Topics covered are CPU operation and timing, address decoding, typical LSI support chips, exception processing, design of static and dynamic memory systems, worst-case timing analysis, bus arbitration, and direct memory access controllers. The laboratory consists of a design project integrating hardware and software using a state-of-the-art development system. PREREQUISITES: EC2800 and EC2820.

II. Text and References

68000 Family Assembly Language, A. Clements, PWS Publishers, 1994.

III. Expected Outcomes

A knowledge of the philosophy of microprocessor based system design using commercial support chips including consideration of software and hardware integration for system implementation. A familiarization with a state-of-the-art development system, worst-case timing analysis, interrupt handling, and hardware and software debugging techniques, and program execution times.

IV. Required Background Experience

1. Combinational logic circuits.
2. Sequential logic circuits.
3. Clocking of digital systems.
4. Digital memory.
5. Arithmetic operations.
6. Assembly language programming.
7. I/O programming.
8. Exception processing.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	The Hewlett Packard 64000 Development System, ABEL.	3 hrs
2.	The 68000 CPU hardware model and timing diagrams.	3 hrs
3.	The 68901 Multi-Functional Peripheral (MFP).	6 hrs
4.	68000 exception processing: traps, interrupts.	3 hrs
5.	The 68230 Parallel Interface/Timer (PI/T).	5 hrs
6.	Designing static memory systems: RAM and ROM.	2 hrs
7.	68000 bus arbitration and alternate bus masters.	1 hr
8.	Designing dynamic memory systems, timing analysis.	2 hrs
9.	Hardware design example: Centronics printer interface.	2 hrs
10.	Program execution times.	4 hrs
11.	Exams and holidays.	3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

This is a lecture course (3 hrs/week) with a laboratory (2 hrs/week). Students take one exam, one final, and submit laboratory reports. Laboratories are about 33% of the grade.

VI. Computer Usage

1. All laboratory assignments involve 68000 assembly language programming. These programs are assembled, linked, and loaded into emulation memory using the HP 64700A emulator system.

2. Two Altera EP310 Erasable Programmable Logic Devices are used in the laboratory projects. These devices are programmed using the ABEL language system running on a Z-248 (AT compatible).

3. Circuit design for the laboratory is done using the STRIDES CAD system running of a Z-248 (AT compatible) with a special accelerator card.

VII. Laboratory

The goal is to make students proficient in designing systems containing microprocessors through a sequence of laboratory exercises which lead from introductory material to completion of a three part design project. Major items of equipment are the HP 64700A Development System and the VT-220 terminals. Tektronix 2336 100 Mhz oscilloscopes and an HP 1615A logic analyzer are used for trouble shooting.

1. HP 64000 Development System familiarization.	2 weeks
2. Interfacing a VT-220 terminal to the 68010 processor.	2 weeks
3. Design of interrupt generation and interrupt acknowledge circuits for a 68010/68901 system; programming an interrupt handler to create a digital time display; integration of an interrupt driven monitor.	3 weeks
4. Creation of a digital temperature display using an LM3911 Temperature Controller, a uA741 operational amplifier, an AD570 A-to-D Converter, and a 68230 PI/T.	2 weeks
5. Music generation using timers in the 68901 and the 68230; interrupt generation and interrupt acknowledge circuits for a 68010/68901/68230 system.	2 weeks

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (35%) Design: 2.5 credit hrs (65%)

B. Design Content

Design of interface units to display temperature and time and to create tones and music by computer. Students are asked to produce both hardware and software to accomplish this.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are required to use the concepts taught in class to create both the hardware and software needed to complete the project. Student creativity is especially important because they are given general direction, rather than specific direction as in prerequisite courses, EC2800 and EC2820.

Development and use of modent design theory and methodology:

Students use design theory and methodology taught in prerequisite courses to verify the correctness of the ABEL designs of the Altera EP310 Erasable Programmable Logic Device.

Formulation of design problem statement and specifications:

Students learn to analyze general system specifications and to translate that to a working system.

Consideration of alternative solutions:

Students have the opportunity to choose alternative solutions in both the software and hardware part of the laboratory project.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Naval Postgraduate School
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Course Coordinator: **F. W. Terman**
Date of Outline Preparation: **2/27/95**
Prepared by: **F. W. Terman**
Revised:

EC3820 COMPUTER SYSTEMS (3-1)

I. Catalog Description

The course presents a unified approach for the design of computer systems stressing the interacting processes implemented in hardware, software, and firmware. General features of operating systems are studied as well as specific features of an existing system. The elements of a multiprogramming system are introduced. PREREQUISITE: EC2800.

II. Text and References

Modern Operating Systems, A. S. Tanenbaum, Prentice-Hall, 1992.

III. Expected Outcomes

A detailed understanding of modern computer systems: process management, input/output, memory management, and the file system. This course also serves as a vehicle for ECE students to learn the UNIX operating system and the C programming language.

IV. Required Background Experience

1 Computer programming in both assembly and high-level languages.
2. Computer organization and processor architectures.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to operating systems.	3 hrs
2. C language tutorial.	3 hrs
3. Processes and interprocess communication.	3 hrs
4. Process scheduling.	3 hrs
5. Memory management: partitioning and swapping.	2 hrs
6. Memory management: paging and segmentation.	2 hrs
7. File systems.	2 hrs

8. System security.		1 hr
9. Input/output.		2 hrs
10. Deadlocks.		2 hrs
11. Case study: UNIX.		3 hrs
12. Case study: MS-DOS.		3 hrs
13. Examinations and holidays.		4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction is by lectures, problem assignments, and programming projects. The course grade is determined as follows: two midterms (40%), final exam (40%), programming projects (15%), and problem assignments (5%).

VI. Computer Usage

The laboratory assignments introduce the students to UNIX, the C programming language, and the operation of the ECE SUN workstation network. Parts of the assignments can be done on a personal computers and then moved to the SUN network.

VII. Laboratory

The goal of the laboratory is to provide the student with an understanding of the UNIX operating system and C programming language. Each student works individually on the project assignments. The laboratory projects are expected to take three hours a week.

1. Introduction to UNIX.	2 weeks
2. Quicksort of a text file (open, close, read, write disk files; dynamically allocate memory; quicksort a pointer array).	5 weeks
3. Interactive memory allocator (create and maintain a linked list of free and allocated blocks of simulated memory).	4 weeks

VIII. Accredation

A. Science/Design Mix

Science: 3 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

Planning and execution of large programs to meet specified objectives.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The laboratory projects develop student creativity by giving the student specifications for the desired outcome, with minimum specifications of the methods to be used to obtain the desired outcome. The student must consider the problem and develop a method to solve it.

Consideration of alternate solution:

The programming projects can be implemented in a variety of ways. The student must consider alternate solutions and determine which one will give the most efficient implementation.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **C. H. Lee**
Date of Outline Preparation: **2/3/95**
Prepared by: **C. H. Lee**
Revised:

EC3830 DIGITAL COMPUTER DESIGN METHODOLOGY (3-2)

I. Catalog Description

A design and project-oriented course covering basic principles, theories, and techniques for practical design of digital systems. Emphasizes an integrated viewpoint combining essential elements of classical switching theory with a thorough understanding of modern design aids. Current military and commercial systems are used as design examples. PREREQUISITE: EC2820

II. Text and References

Text:

Digital Design Principles and Practices, J. F. Wakerly, Prentice-Hall, Inc.

Digital System Design Using VHDL, C. H. Lee, CorralTeck.

Alternate Text:

Digital Design Fundamentals, K. Breeding, Prentice Hall,1989.

III. Expected Outcomes

A knowledge of the theoretical background and the modern design tools used in the design of large scale digital systems. The laboratory introduces modern computer design tools in the context of several design laboratories and projects.

IV. Required Background Experience

1. Binary number systems and binary arithmetic.
2. Boolean algebra.
3. Switching function minimization using Karnaugh maps.
4. Switching function realization with MSI devices.
5. Flip-flops and latches.
6. Synchronous sequential machine design.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Combinational logic design, Quine-McClusky algorithm.		3 hrs
2. MSI level combinational circuit design.		2 hrs
3. Minimization of multiple output switching function.		2 hrs
4. Hardware description language VHDL.		5 hrs
5. Structural and data flow system description.		6 hrs
6. Synchronous sequential logic circuit.		3 hrs
7. State simplification, machine models.		3 hrs
8. High speed adders and multipliers.		3 hrs
9. Top down system design.		6 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture laboratory mode of instruction is used. The course will have at least one mid-term exam plus a regularly scheduled final exam or final project.

VI. Computer Usage

The laboratory involves the use of the Mentor Graphics design capture CAD system running on SUN workstations with the Quicksliver II logic simulator. A laboratory project on controller design is also given to introduce the modern design methodology.

VII. Laboratory

Design and simulation of switching functions and clocked sequential machines. Schematic capture, logic simulation, hardware description language, digital controller, and final project are involved.

VII. Accreditation

A. Science/Design Mix

Science: 1 credit hr (25%) Design: 3 credit hrs (75%)

B. Design Content

Students are involved in digital circuit design at the homework and laboratory levels. A majority of the homework involves exercises that require students to construct a logic circuit according to functional specifications. Students are using computer aided design packages such as Mentor Graphics software tools, perform various steps involved in the modern design methodology: schematic capture, simulation, system description using VHDL hardware description language, and circuit synthesis tools.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Laboratory requires students to design a multiplier controller. They have to use all learned skills plus creativity to accomplish the final project.

Development and use of modern design theory and methodology:

Students study hardware description language for system description and do three VHDL labs. Mentor schematic capture, simulation tools are used in the labs.

Formulation of design problem statement and specifications:

VHDL hardware description language is used to specify system for automatic synthesis and design rule checking.

Consideration of alternative solution:

Students need to explore alternative solutions in the controller design laboratory. Evaluation of the controller design is based on time and circuit cost trade-off.

IX. Educational Skills Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Naval Postgraduate School
Department of Electrical and
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Course Coordinator: **D. J. Fouts**
Date of Outline Preparation: **1/12/95**
Prepared by: **D. J. Fouts**
Revised:

EC3840 INTRODUCTION TO COMPUTER ARCHITECTURE (3-2)

I. Catalog Description

Introduction to computer organization. Fundamental principles of computer design and cost/performance. Instruction set design and usage. Processor design and implementation, including the data path and the control unit. Computer design, including buses, the memory hierarchy and the input/output subsystem. Factors effecting performance and performance measurement/evaluation. The effects of embedded military applications on computer architecture. PREREQUISITES: EC2800 and EC2820.

II. Text and References

Computer Organization and Design: The Hardware/Software Interface, D. A. Patterson and J. L. Hennessy, Morgan Kauffman Publishers, Inc., 1994.

III. Expected Outcomes

The student will learn the basic information necessary to design processors and computer systems, and to manage projects involving the design, implementation, procurement, and operation of processors and computer systems. The fundamental concepts necessary for advanced study in the area of computer architecture will also be learned. The student will also gain first-hand knowledge of the use and availability of CAD tools for simulating and analyzing computer architectures and designing computers and other digital systems.

IV. Required Background Experience

1. Logic design.
2. Assembly language programming.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction, including levels of abstraction, implementation technology, and a brief history of computers.		2 hrs
2. Factors effecting performance, cost/performance, and performance measurement/evaluation.		2 hrs
3. Instruction set design, machine language, assembly language, and the role of assemblers and compliers.		5 hrs
4. Processor design, including the data path and the control unit.		7 hrs
5. Processor implementation, including discrete component implementation, VLSI implementation, the effect of the architecture and the instruction set on the implementation, and the use of CAD tools.		2 hrs
6. The memory hierarchy, including the register file, cache memory, main memory, secondary memory, virtual memory, and memory subsystem performance.		5 hrs
7. Input/output subsystems, including devices, interfaces, standards, and performance.		4 hrs
8. Military computer systems.		2 hrs
9. Exams, holidays, and miscellaneous.		4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

The lectures cover the following chapters in the textbook: 1) Computer Abstractions and Technology, 2) The Role of Performance, 3) Instructions: Language of the Machine, 5) The Processor: Datapath and Control, 7) Large and Fast: Exploiting Memory Hierarchy, 8) Interfacing Processors and Peripherals. Other material supplements the textbook at the discretion of the instructor. Homework and laboratory assignments on each chapter are made when the chapter is started in lecture. Homework assignments are not collected, but solution sets are handed out when lectures on a chapter are finished. Laboratory reports are due one week after lectures on a chapter are finished. Laboratory reports are graded and returned to the students. There are one or two midterm exams, as deemed necessary by the instructor, and one final exam.

VI. Computer Usage

All students will need an account on the ECE department workstation network. Computer use will be approximately two hours per week.

VII. Laboratory

Laboratory work utilizes an integrated set of advanced CAD tools for designing, implementing, simulating, and programming a modern RISC processor. Laboratory time is approximately two hours per week.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Computer architecture and instruction-set design, logic design, design of test vectors for digital systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Laboratory and homework assignments require students to be creative with respect to the architecture and high-level design of processors and the low-level logic design of digital systems.

Use of open ended problems:

The sequence of laboratory assignments require students to design a processor that implements a specified instruction-set architecture. This is a problem that has multiple solutions and requires an iterative process to arrive at a reasonable solution that cannot be proven to be optimal.

Development and use of modern design theory and methodology:

All of the laboratory assignments emphasize modern design, implementation, and simulation techniques, and use up-to-date CAD tools.

Formulation of design problem statement and specifications:

The sequence of laboratory assignments requires students to specify a hardware design that will implement the given instruction-set architecture.

Consideration of alternative solution:

The sequence of laboratory assignments requires students to consider alternative solutions at every step of their design.

Feasibility Considerations:

During lab, students are only allowed to use parts that are available in the TTL handbook. Therefore, their designs are bounded by real-world restrictions.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **S. B. Shukla**
Date of Outline Preparation: **9/94**
Prepared by: **S. B. Shukla**
Revised: **1/95**

EC3850 COMPUTER COMMUNICATIONS METHODS (3-0)

I. Catalog Description

The course objective is to develop an understanding of computer communications networks with emphasis on the requirements of military environments and the US Navy's combat platforms. Coverage includes the essential topics of network topology, connectivity, queuing delay, message throughput, and cost analysis. The layered network architectures, such as the International Standards Organization (ISO) model and GOSIP consisting of the physical, data link, network, transport, session, presentation, and application layers, are covered. The techniques and protocols used in these layers are discussed. Local area networking technologies such as Ethernet, ring, satellite link, X.25 public packet switching, and FDDI are covered. PREREQUISITE: EC2010

II. Text and References

Data and Computer Communications, W. Stallings, 4th Ed., MacMillan.

III. Expected Outcomes

A knowledge of basic results, technological developments and standards in the area of computer communications.

IV. Required Background Experience

1. Probability theory.
2. Ability to program in a high level language, such as FORTRAN , ADA, or C.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to computer communication.	1 hr
2. Computer system features essential for networking.	1 hr
3. The ISO, GOSIP reference models.	3 hrs

4. Topology, connectivity, message delay, cost analysis.		3 hrs
5. Backbone and access network design.		2 hrs
6. The physical layer.		1 hr
7. The data link layer.		4 hrs
8. The network layer.		4 hrs
9. Introduction to the transport layer.		1 hrs
10. Satellite and packet radio networks.		2 hrs
11. Local area networks.		6 hrs
12. Network applications.		1 hr
13. Case study.		1 hr
15. Exams and holidays.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-demonstration mode of instruction is used. The course will either have 1) at least three exams or, 2) two exams and detailed project assignments.

VI. Computer Usage

Computer programs are developed by the students for data link control and performance analysis of local area networks. Whenever possible, a commercial network engineering tool, OPNET, or MATLAB is used.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (50%) Design: 1.5 credit hrs (50%)

B. Design Content

Students use computer aided modeling/analysis packages aimed at networks, such as OPNET or mathematical software packages (MATLAB) to model the protocols and/or subsystems in computer networks.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students must specify the packet arrival rates, buffer sizes, timeout values to get the desired performance from the network subsystem under study, such as a data link or a local area network.

Development and use of modern design theory and methodology:

Students study a hierarchical modeling methodology understanding the different nested components of networks. Reading assignments from professional texts and questions based on them emphasize the practical aspects.

Formulation of design problem statement and specifications:

Students use the queuing models studied in class in conjunction with the OPNET tool to build simulations with part of the parameter values supplied.

Consideration of alternative solution:

The specification of the laboratory assignments require the students to structure the problem as per their own understanding of the network components and their interrelationships.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications

systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **5/19/95**
Prepared by: **C. W. Therrien**
Revised:

EC3910-3990 SPECIAL TOPICS IN ELECTRICAL ENGINEERING (0-8)

I. Catalog Description

Courses on special and advanced topics in Electrical Engineering are developed under these headings. In most cases new courses are offered as special topics of current interest with the possibility of being developed as regular courses.

II. Text and References

Depends on instructor and/or course content.

III. Expected Outcomes

Familiarization of advanced topics of current interest in electrical engineering.

IV. Required Background Experience

Varying according to the instructor and the content of the course. Prerequisites of EC courses at the 2000 and 3000 level are usually expected.

V. Detailed Description of the Course

A. Expanded Description of the Course

The content of this course will vary according to the topic.

B. Method of Instruction and Evaluation

According to the content, along the lines of regularly scheduled 3000 level courses in the ECE Department.

VI. Computer Usage

Although the course topics vary, assignments will be designed towards computer-aided analysis, a design, and/or the development of computer algorithms to support the material covered in class. Students use MATLAB or specialized software in computer-aided design problems.

VII. Laboratory

According to the topic.

VIII. Accreditation

A. Science/Design Mix

Variable, according to topic, instructor.

B. Design Content

Variable.

C. Design Attributes

Depends on particular offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R. W. Hamming**
Date of Outline Preparation: **3/13/95**
Prepared by: **R. W. Hamming**
Revised:

EC4000 FUTURE ENGINEERING PRACTICE (3-0)

I. Catalog Description

This course discusses the fundamental concepts and practices of electrical engineering history, especially computer simulations (including AI), so that students can see trends and make some guesses as to their future. It primarily concentrates on students and their problems in learning new things as technology and careers continue to progress. The course, to some extent, adapts itself to the interests of the students enrolled, but much is a survey of the fundamentals of engineering theory and practice and projections into the future. PREREQUISITE: Consent of the instructor. Graded on Pass/Fail basis only.

II. Text and References

The Art of Doing Science and Engineering, R. W. Hamming (in publication).

III. Expected Outcomes

Students will understand the fundamentals of engineering theory and be able to make intelligent projections into the future. Students will learn the importance of the style of approaching topics and problems.

IV. Required Background Experience

Exposure to undergraduate and graduate technical courses.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. History of computing, hardware, software.	3 hrs
2. Limits of machine applications; A.I.	3 hrs
3. Review of basics of coding theory.	3 hrs
4. Review of digital filters in the context of signal processing.	3 hrs
5. n-dimensional space and its relation to the design.	2 hrs
6. Data bases and the problem of accuracy.	1 hr

7. Computer-aided instruction (use and misuses). 1 hr
8. Optical fibers - trends and value to the Navy. 1 hr
9. Role of computers in the future Navy. 2 hrs
10. Topics of the class's choosing. 6 hrs
11. Numerical analysis. 7 hrs
12. Final lecture: Doing great things with your life in the Navy. 1 hr

TOTAL 33 hrs

B. Method of Instruction and Evaluation

The method of instruction is by lecture only. There are no exams.

VI. Computer Usage

None

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (100%) Design: 1 credit hr (0%)

B. Design Content

The course discusses and emphasizes creative approaches to problem solving through anecdotes based on past experiences. The course uses material previously taught, or what should be in their education, and discusses how things are in practice as opposed to theory. However, students are not expected to complete any projects requiring design.

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **D.v.Z. Wadsworth**
Date of Outline Preparation: **10/19/93**
Prepared by: **D.V.Z. Wadsworth**
Revised: **2/17/95**

EC4010 PRINCIPLES OF SYSTEMS ENGINEERING (3-2)

I. Catalog Description

An introduction to systems engineering concepts and methods for the design and integration of complex defense systems, with emphasis on electrical engineering applications. Familiarity with the systems engineering process is developed through case studies of representative defense systems and a group design project which includes determination of system requirements from mission needs and operational requirements. Digital simulation models, including those in current use by DOD, are used to determine engineering and performance tradeoffs. PREREQUISITES: Four quarters in an NPS engineering curriculum or equivalent.

II. Text and References

Texts:

Systems Engineering and Analysis, 2nd, Ed., B. S. Blanchard and W. J. Fabrycky, Prentice-Hall, 1990.

System Engineering Management Guide, Defense Systems Management College, 1990.

Reference:

Intermediate Systems Planning, Research, Development, and Engineering, Army Management Engineering College, Jan. 1995.

III. Expected Outcomes

Working knowledge of the systems engineering process for the specification, design, and development of complex defense systems, including the interdisciplinary project team and subsystem integration.

IV. Required Background Experience

1. Prior engineering/physics education at the BS level or completion of four quarters in an engineering curriculum at NPS.
2. Probability and statistics.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to the systems approach and system life cycle; review of the system acquisition process and DOD contractor relationships (DOD RDT&E categories, program phases and milestones, MNS, ORD, ATD, COTS/NDI, ATD, PPI, RFP, SOW, CDRL, configuration control, SEMP, TEMP, WBS, GANTT charts, concurrent engineering, subsystem integration, functional analysis and synthesis, engineering specifications, MIL_standards).	4 hrs
2. Introduction to system engineering topics (reliability, availability, maintainability, logistics support, training, cost, producibility, manability, safety, risk, etc.).	4 hrs
3. Class project (instructor in role of PM or advisor.	12 hrs
4. Case studies (involving selected topics from A2).	6 hrs
5. Project presentation.	4 hrs
6. Exams and holidays.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

Lectures and reading assignments plus a major team design project. Projects are graded.

VI. Computer Usage

Depends on selected class project, digital simulation models, including those in current use by DOD, may be used to determine engineering and performance tradeoffs. May require MS-DOS or WINDOWS on a 486-PC platform or UNIX on a SUN-Sparc platform.

VII. Laboratory

None

VII. Accreditation

A. Science/Design Mix

Science: 1 credit hr (25%) Design: 3 credit hrs (75%)

B. Design Content

The case studies and team projects involve the design of representitive military electronics systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to participate in system design of a complex military system, including integration of subsystems.

Use of open ended problems:

The system design problems are open ended requiring analysis of mission needs, trade studies, and systems engineering processes.

Formulation of design problem statement and specifications:

Each student is required to determine the specifications for his/her system.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **J. G. Ciezki**
Date of Outline Preparation: **2/8/95**
Prepared by: **J. G. Ciezki**
Revised:

EC4130 Advanced Electrical Machinery Systems (4-2)

I. Catalog Description

Advanced analysis of detailed and reduced-order representations of shipboard electrical machinery and power electronic drives. This course will include extensions to 3-phase machine and network connections, constant flux and current source control, extensive simulation examples including saturation and open-phase conditions, comprehensive investigation of linearized and reduced-order machine and drive representations, the modeling and control of a dc link system, and the fundamentals of induction machine vector control. PREREQUISITE: EC3130.

II. Text and References

Analysis of Electric Machinery, P. C. Krause, O. Wasynczuk, and S. D. Sudhoff, McGraw-Hill, 1986.

Course notes.

III. Expected Outcomes

Students will acquire the abilities to develop numerical simulations of electric machines and power converters, to utilize the digital simulations to predict stability and performance and design appropriate feedback controls, to analytically devise voltage/frequency relationships which guarantee rated flux operation for voltage source and current source operation of the induction machine and the reluctance machine, and to employ field-oriented vector control in high-fidelity electromechanical actuation applications.

IV. Required Background Experience

1. Ability to write voltage and flux linkage equations for 2-phase machines.
2. Ability to manipulate matrices and vectors.
3. Ability to do basic programming in ACSL.
4. Ability to do basic programming in MATLAB.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Introduction to course objectives; review of 2-phase machine analysis.	1 hr
2.	Analysis of 3-phase machines: establishing the mmf, stator and rotor inductances for round-rotor and salient-pole devices.	3 hrs
3.	Reference frame theory: transformation to the arbitrary reference frame, application to R, L, and C components, commonly used reference frames, transformations between frames, transformation of a balanced set, phasor relationships, variables in different frames.	4 hrs
4.	Analysis of 3-phase induction machines: voltage and flux linkage equations, torque equation, equations of transformation, transformation to the arbitrary reference frame, flux linkages per second, analysis in the steady state.	4 hrs
5.	Constant flux operation of the induction machine; derivation of a constant flux voltage/frequency relationship.	2 hrs
6.	Analysis of current source operation: at rated frequency, torque/speed curve, choice of operating point, constant flux operation, variable frequency extensions, control configuration.	2 hrs
7.	Simulation of induction machines: choice of reference frame, saturation, open phase.	2 hrs
8.	Analysis of 3-phase synchronous machines: voltage and flux linkage equations, torque equation, equations of transformation, rotor reference frame analysis, analysis in the steady state, phasor diagrams, determination of the rotor angle, infinite bus operation.	5 hrs
9.	Synchronous machine control: synchronous and self-synchronous.	1 hr
10.	Linearized machine analysis: Taylor series, induction machine, operating point determination, transfer functions, stability, synchronous machines, output feedback stabilization.	4 hrs
11.	Reduced-order equations: neglecting stator electric transients, induction machine, synchronous machine, simulations, comparison with detailed models.	3 hrs
12.	Algebraic loops; voltage-behind-reactance machine models; Interconnecting machine models; Determination of the network admittance matrix.	2 hrs
13.	Electronic converters and ac machines: 1 and 3-phase, phase-controlled rectifiers, 3-phase voltage source inverters, pulse-width modulation.	3 hrs

14.	Analysis, simulation, and reducted-order modeling of a dc voltage link system, evaluation of accuracy.	2 hrs
15.	3-phase current source analysis: commutation, reduced-order model, closed-loop design.	2 hrs
16.	Vector control: steady-state analysis, dynamic analysis, direct and indirect implementation, control structures.	4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

Lectures consist of a prepared skeleton of notes that the student completes during the discussion. Hands-on laboratory experiments and computer simulation projects reinforce the theoretical principles introduced in lecture. The student is graded on a midterm exam, a final exam, six computer and design projects, as well as five laboratory investigations.

VI. Computer Usage

Assigned simulation projects will be completed using ACSL or SIMULINK. Computer accounts are set up on the Sparc10 workstations within the power laboratory for the students' convenience. Addditional stability and operating point analysis problems will be solved using MATLAB. The appropriate M-files will be supplied by the instructor or will be written by the student.

VII. Laboratory

Working in groups of two or three, the students perform the following electromechanical device experiments and computer projects:

Hardware Experiments:

1.	Determination of 3-phase induction machine parameters.	2 hrs
2.	Starting characteristics of a 3-phase synchronous machine.	2 hrs
3.	Power factor control of a 3-phase synchronous machine.	2 hrs
4.	Synchronizing an alternator to the electric power grid.	2 hrs
5.	The characteristics of the wound rotor induction machine.	2 hrs

Software Experiments:

6.	Simulation of a 3-phase induction machine.	2 hrs

7.	Simulation of an induction machine speed control system.	2 hrs
8.	Simulation of a 3-phase reluctance machine.	2 hrs
9.	Simulation of a shipboard power system.	2 hrs
10.	Simulation of a representative shipboard electric drive.	2 hrs
11.	Midterm exam.	2 hrs
	TOTAL	22 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (60%) Design: 2 credit hrs (40%)

B. Design Content

Computer projects involve the synthesis of digital-based electromechanical device and power converter models which are then incorporated into various control system configurations. The student then uses the simulation to determine appropriate control gains, assess system stability, make comparisons between detailed and reduced-order models, and investigate modifications to the control law. Laboratory experiments require students to use electronic measurement techniques to structure tests to determine device parameters.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student must develop, test, and be able to demonstrate the simulation of various power conversion apparatus. The student must then exercise the simulation to assess stability and design stabilizing controls.

Consideration of alternate solutions:

Design projects provide a solution framework but ultimately rely on the students to consider appropriate modifications to improve the robustness and response of the solution.

Realistic constraints on design:

Each simulation project emphasizes the multi-input, multi-objective, nonlinear nature of electric drive synthesis. The student must recognize and account for magnetic saturation, underutilization of the machine iron, current ratings, integrator anti-windup, and control saturation.

Development and use of modern design theory and methodology:

The students extensively use reference frame analysis and reduced-order modeling techniques to transform highly nonlinear phenomenological processes to tractable mathematical problems.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **R. W. Ashton**
Date of Outline Preparation: **2/17/95**
Prepared by: **R. W. Ashton**
Revised:

EC4150 Advanced Solid State Power Conversion (4-1)

I. Catalog Description

Design and analysis of modern power electronic drives with particular emphasis on electric drives for present and future ship propulsion systems and variable frequency/variable speed power converters for advanced shipboard electric power distribution. Electrical and mechanical systems compatibility and electrical system interfacing topics are addressed. This course begins by examining the non-ideal aspects of power semiconductor switches and other components. In addition, dynamic performance of power electronic circuits is explored. The course includes some more advanced topics like resonant converters and active power line conditioners. PREREQUISITES: EC3150 and electrical machine theory, or consent of instructor.

II. Text and References

Text:

Power Electronics, M. J. Fisher, PWS-Kent Publishing, 1991.

References: Handouts.

III. Expected Outcomes

The student will gain an understanding of solid state motor drives and several specialized types of converters of interest to the Navy. Power system harmonics and active power line conditions are also presented. In addition, the course introduces current research in power systems.

IV. Required Background Experience

1. Single and three phase power.
2. ac transformers.
3. Line frequency controlled rectifiers (dc load line).
4. Single phase ac voltage control.

5. Single and three phase PWM inverters.
6. dc-to-dc converters.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Power diodes.		4 hrs
2. Thyristors.		4 hrs
3. Power transistor switches.		4 hrs
4. Phase controlled rectifiers.		1 hr
5. dc-to-dc converters.	3 hrs	
6. Design consideration.		4 hrs
7. Current research topics.		4 hrs
8. Resonant converters.		4 hrs
9. Cuk converter.		4 hrs
10. Active power line conditioner.		4 hrs
11. Harmonics in power systems.		4 hrs
12. Motor drives.		4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

The course material is presented in lecture format. Grading is based on homework, laboratory, a midterm presentation, and a major design project.

VI. Computer Usage

The SIMULINK environment inside MATLAB will be used for the modeling of dc-to-dc converters. The modeling will incorporate a controller and be based on the state space average technique.

VII. Laboratory

1. Non-ideal components.		1 hr
2. Flyback converter.		1 hr
3. Resonant converters.		1 hr
4. Cuk converter.		1 hr
5. Active power line conditioner.		1 hr
6. Design project.		6 hrs
	TOTAL	11 hrs

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%) Design: 2 credit hrs (45%)

B. Design Content

Both the homework problems and the major project arecentered around design. All aspects are covered: initial problem statement, research, modeling, analysis building, testing, redesign and presentation. The students are expected to make a working usable project.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The student is expected to take an active role in a group assigned power electronics major design project. Performance on an individual and group basis is evaluated. The project must function for a grade, therefore it is necessary that the problem encountered by solved with the available resources.

Use of open ended problems:

The group design project and many homework problems have only general characteristics assigned to them. Therefore, the students must determine where to stop and how to approach and analyze results. Because of the scope of these problems, they are open ended.

Development and use of modern design theory and methodology:

The group is expected to design, build, test, analyze, simulate, and present their project. Principles discussed in class such as device protection techniques, non-ideal component analysis, state space average modeling, etc., are considered essential for proper design, functioning, and understanding of the project.

Formulation of design problem statement and specifications:

The class is divided into several groups for a major power electronics design project. Each member of the group must play a significant role. All design projects must work on exam day. Groups must complete a minimum of the following: project goals and summary, block diagram of concept, complete schematic diagram, test procedure and results, modeling equations, simulation results, variations between simulation and hardware results, and problems encountered and solutions.

Consideration of alternate solutions:

In the process of building and testing each phase of the design project and incorporating the separate pieces into a whole functioning unit, problems are encountered. This ultimately requires a reevaluation of the design process and other solutions needed to be used. This is inevitable due to the nature of power electronics. A project that works at low power levels nearly always needs modification to meet the high power final requirements in the general specifications.

IX. Educational Skill Requirements (ESRs)

This course support the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

This course also supports ESRs for curriculum 595 and 596 (Electronic Warfare): Electrical Engineering and Electronic Warfare.

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Course Coordinator: **R. J. Pieper**
Date of Outline Preparation: **3/16/95**
Prepared by: **R. J. Pieper**
Revised:

EC4210 ELECTRO-OPTIC SYSTEMS ENGINEERING (3-0)

I. Catalog Description

Advanced topics and application of electro-optics. Military applications of electro-optic and infrared technology such as laser communications, laser radar, and Bragg cell signal processors. Signal-to-noise analysis of laser detector performance. Student reports on EO/IR topics of current military interest. PREREQUISITE: EC3210.

II. Text and References

Class notes provided by instructor.

III. Expected Outcomes

Students will learn about the integration of electro-optical components for noncoherent and coherent electro-optic systems. Application of these electro-optic systems will be elaborated by a term paper on different areas selected by students. For example, the special areas could be offensive applications such as high energy laser weapons, weapon guidance by coherent and/or noncoherent devices, or defensive applications such as surveillance systems or search and tracking systems. Other applications are communication systems and optical computing.

IV. Required Background Experience

1. Generation of coherent and incoherent light - lasers and black body radiation.
2. Properties of light - polarization, coherence, monochromaticity.
3. Manipulation of light - mirrors, lenses, polarizers, etc.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Electro-optic modulation of light.	3 hrs
2. Acousto-optic modulation of light, Bragg cells, beam	3 hrs

deflectors, of signal processing.

3.	Optical detector noise.	2 hrs
4.	Signal-to-noise analysis of photomultipliers: direct and heterodyne detection, response speed and bandwidth.	3 hrs
5.	Signal-to-noise analysis of photoconductors: direct and heterodyne detection.	3 hrs
6.	Signal-to-noise analysis of photodiodes and avalanche photodiodes: direct and heterodyne detection, background-limited detection.	3 hrs
7.	Infrared detectors and systems analysis.	3 hrs
8.	Student reports.	11 hrs
9.	Exams.	2 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture method of instruction is used. Homework assignments, exams, and a project are counted for the final grade.

VI. Computer Usage

None

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

Students are required to prepare a project in which one of two conditions must be met: They must either confirm using computer simulation, some fairly current engineering model, or design that has appeared in the literature; or they must propose their own design and/or model and test it on the computer.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

In either of the cases mentioned above, the student must develop a familiarity with a problem which can be characterized in terms of design and modeling. Because each project is different, there is significant potential for student creativity. The guidelines for the project are based on a scaled-down approach typically employed here for NPS theses.

Use of open ended problems:

Students are required to prepare a report and make a class presentation summarizing independent work involving computor simulations on a problem related to optical devices and detection.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Naval Postgraduate School
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Course Coordinator: **S. Michael**
Date of Outline Preparation: **5/11/94**
Prepared by: **S. Michael**
Revised: **4/28/95**

EC4220 INTRODUCTION TO ANALOG VLSI (3-1)

I. Catalog Description

Modern active circuit design topologies; analog and sampled data networks. Analysis of transfer function properties, stability and causality. Higher order filter design and synthesis. Use of computer simulation tools, SPICE, and different device models for network analysis. Transformation methods and switched-capacitor filtering and non-filtering applications. Introduction to analog VLSI techniques using stray-insensitive switched-capacitor networks. Examples of such analog VLSI designs in military applications. PREREQUISITE: EC2400 and EC3200.

II. Text and References

Design of Analog Filters, Passive, Active RC, and Switched Capacitor, Schaumann, Ghausi, & Laker, Prentice-Hall, 1990.

Analog MOS Integrated Circuits for Signal Processing, Gregorian & Temes, Wiley Interscience, 1986.

III. Expected Outcomes

This course is designed to introduce the students to the different techniques utilized in modern active circuit design. Students will use the latest software design tools in network analysis and design and will become familiar with state-of-the-art analog VLSI technology using switched-capacitor networks.

IV. Required Background Experience

1. Analysis of electronic circuits.
2. Analysis of operational amplifier circuits.
3. Determining transfer functions for linear networks.
4. Familiarity of the z-transform.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to network functions and filter classifications.	2 hrs
2. Transformation methods.	1 hr
3. Sensitivity analysis and stability of transfer functions.	4 hrs
4. Continuous time active filters.	6 hrs
5. Computer simulation methods and modeling using SPICE.	2 hrs
6. Higher order filter realizations (filter synthesis).	3 hrs
7. Switched Capacitor (SC) networks.	8 hrs
8. SC filtering and nonfiltering applications.	2 hrs
8. Application of active networks in analog NLSI design.	3 hrs
9. Military applications of analog VLSI.	2 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

This course is project oriented. There will be a mid-term exam and two major projects where the final project constituting 50% of the final grade.

VI. Computer Usage

1. Three homework assignments for testing transfer functions stability and sensitivity, using MATLAB.

2. Two homework assignments for filter simulation and analysis using SPICE, MICROCAP, and different devices models.

3. Use of the above computer simulation techniques for designing two projects: a continuous and a sampled data filter.

VII. Laboratory

1. Designing and implementing a high order continuous active filter; a report including theoretical design, computer simulation and experimental verifications is required.
2. A sampled data version of the above project is designed and implemented with similar report.

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (45%) Design: 2 credit hrs (55%)

B. Design Content

The laboratory exercises in this course involve design of different electronic circuits at the introductory level.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

The laboratories require the students to design and construct electronic circuits to meet certain specifications, and then test and verify their design.

Design theory and methodology:

Students study device modelling and use circuit simulation programs (SPICE) to simulate and analyze their designs to verify that they meet the requirements according to the theory.

Use of open ended problems:

There are no unique solutions for the design problems the students are required to do, thus students are faced with open ended choices of components and circuit topologies.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R. Cristi**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC4300 ADVANCED TOPICS IN MODERN CONTROL SYSTEMS (3-0)

I. Catalog Description

Advanced topics and current developments in control systems are presented in this course. The list of special topics includes (but it is not limited to) robotics systems, autonomous vehicles, design by robust techniques. PREREQUISITE: Consent of instructor.

II. Text and References

Depends on instructor and/or course content.

III. Expected Outcomes

Familiarization with a selection of advanced topics in control theory through student research and project presentations.

IV. Required Background Experience

The content of this course will vary with the instructor and interests of the class.

V. Detailed Description of the Course

A. Expanded Description of the Course

The content of this course will vary with the instructor and interests of the class.

B. Method of Instruction and Evaluation

Major emphasis to computer projects, possibly in conjunction with current literature research, and oral presentation.

VI. Computer Usage

Although course topics vary, assignments will be designed towards computer-aided analysis, a design, and/or the development of computer algorithms to support the material covered in class. Students use MATLAB or specialized software in computer aided design problems.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Variable, according to topic, instructor.

B. Design Content

Variable

C. Design Attributes

Variable, dependent on topic at offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data

acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **G. Hutchins**
Date of Outline Preparation: **5/2/95**
Prepared by: **R. Cristi**
Revised:

EC4320 DESIGN OF ROBUST CONTROL SYSTEMS (3-2)

I. Catalog Description

This course presents advanced topics on control system design. Major emphasis is on robust techniques in order to account for uncertainties on the systems to be controlled. Several applications show the trade-offs in several applications, such as missile and/or underwater vehicles control design. Advanced concepts on H2 and H-infinity will be introduced as part of the course. PREREQUISITES: EC3310, EC3320.

II. Text and References

Linear Robust Control, M. Green and D. L. Limebeer, Prentice-Hall, 1995.

III. Expected Outcomes

The students will learn how to design control systems to be applied to real world situations. Optimality in the presence of modeling uncertainties will be the main goal. Both theory and implementations will be addressed and the students will learn sufficient theoretical principles to make them understand the real world applications.

IV. Required Background Experience

1. Classical optimal control (linear quadratic regulator).
2. Optimal recursive estimation using state space models.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Advanced topics in frequency domain design for linear control systems.	6 hrs
2. Linear quadratic Gaussian controller design.	3 hrs
3. Robust LQG design and loop transfer recovery.	6 hrs
4. Introduction to normed function spaces and functional	3 hrs

analysis.

5. H-infinity control in the frequency domain. 6 hrs
6. Design of H-infinity controllers in the time domain. 6 hrs
7. Issues in implementations. 3 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The computer projects will be individual, and their aim is to a) develop mathematical models for physical systems using data collected from experiments and b) design, test, and evaluate adaptive control techniques from computer simulations. Topics of the projects will be as follows:

1. Design and test an LQG controller for a physical system with uncertain dynamics (typically a missile or a submarine), using MATLAB and/or SIMULINK. Test the effectiveness of coping with changing dynamics;
2. Same as in 1., using Loop Transfer Recovery (LTR). Compare the results obtained;
3. Same as in 1., using an H-infinity controller.
4. Compare the results obtained using the techniques presented. Comparison will be on the basis of overall performance and robustness in the presence of dynamic uncertainties.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity

All projects require the students to develop computer programs related to the theory developed in the lectures. Also, the students have to make educated choices between different design techniques and evaluate performances and trade-offs.

Formulation of design problem statements and specifications

Each student is required to apply theoretically developed techniques to the design of optimal control of physical systems. For each design problem the specifications will be given in line with commonly used engineering practice.

Use of open ended problem

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade-off of various techniques by computer simulations.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data

acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **H. Titus**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC4330 NAVIGATION, MISSILE AND AVIONICS SYSTEMS (2-2)

I. Catalog Description

Principles of operation of navigation, missile, and avionics systems are presented. Topics are selected from the following areas to address the specific interests of the class: IR, radar laser, and acoustic sensors; inertial platforms; gyros and accelerometers; Loran, Omega, GPS, INS guidance, fire control and tracking systems. PREREQUISITES: EC3310, EC2320, U.S. citizenship and SECRET clearance.

II. Text and References

Tactical and Strategic Missile Guidance, P. Zarcan, AIAA, 1990.
Instructor's notes.

III. Expected Outcomes

An introductory level of knowledge of navigational guidance and control of tactical missiles currently in use by the U.S. military establishment.

IV. Required Background Experience

1. Classical control analysis and design techniques.
2. Optimal filtering of random signals.
3. Modern and optimal control techniques.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Guidance LOS, CLOS, PN seekers.	8 hrs
2. Missile aerodynamics.	4 hrs
3. Missile autopilots.	2 hrs
4. Instrumentation (INS, GPS, gyros, etc.).	5 hrs

5. Target trackers. 3 hrs

TOTAL 22 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The computer projects will be individual and they all aim at the application of optimal filtering and tracking techniques in a computer simulated environment. Topics of the projects will be as follows:

1. Boost phase intercept missile design.
2. Point defense missile for anti-ship missiles
3. Multisensor missiles.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (65%) Design: 1 credit hr (35%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

All projects require the students to develop computer programs related to the theory developed in the lectures. Also the students have to make educated choices between different design techniques and evaluate performance and trade offs.

Use of open ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade off of various techniques by computer simulations.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal controls for missiles. For each design problem the specifications will be given in line with commonly used engineering practice.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **H. Titus**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC 4340 NAVIGATION, MISSILE AND AVIONICS SYSTEM (2-2)

I. Catalog Description

This course covers essentially the same material as EC4330, but with deletion of detailed analysis of specific systems. This course is intended for officers who do not have U.S. citizenship. PREREQUISITES: EC2320, EC3310.

II. Text and References

Tactical and Strategic Missile Guidance, P. Zarcan, AIAA, 1990.

Instructor's notes.

III. Expected Outcomes

Introduction to navigational guidance and control of tactical missiles

IV. Required Background Experience

Classical control concepts (Bode and root locus), ability to solve control problems using optimal control theory, and familiarity with the Kalman filter approach to linear filtering and prediction problems.

V. Detailed Description of the Course (Unclassified discussion)

A. Expanded Description of the Course

1. Guidance LOS, CLOS, PN seekers.		8 hrs
2. Missile aerodynamics.		4 hrs
3. Missile autopilots.		2 hrs
4. Instrumentation (INS, GPS, gyros, etc.).		5 hrs
5. Target trackers.		3 hrs
	TOTAL	22 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/SIMULINK.

VII. Laboratory

The computer projects will be individual and they all aim at the application of optimal filtering and tracking techniques in a computer simulated environment. Topics of the projects will be as follows:

1. Boost phase intercept missile design.
2. Point defense missile for anti-ship missiles.
3. Multisensor missiles.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (65%) Design: 1credit hr (35%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

All projects require the students to develop computer programs related to the theory developed in the lectures. Also the students have to make educated choices between different design techniques and evaluate performance and trade offs.

Use of open ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade off of various techniques by computer simulations.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal controls for missiles. For each design problem the specifications will be given in line with commonly used engineering practice.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **H. Titus**
Date of Outline Preparation: **11/21/94**
Prepared by: **R. Cristi**
Revised:

EC4350 NONLINEAR CONTROL SYSTEMS (3-2)

I. Catalog Description

This course presents techniques for automatic control of nonlinear systems with application to current military and robotic systems. Main topics include the analysis and design of nonlinear systems with phase plane and describing function methods, Lyapunov and sliding mode control techniques. Acurracy limit cycles, jump resonances, relay servos, and discontinuous systems will also be considered. PREREQUISITES: EC2300, EC2320.

II. Text and References

Applied Nonlinear Control, J. J. E. Slotine and W. Li, Prentice-Hall, 1991.

III. Expected Outcomes

The intent of this course is to provide a familiarization with the physical and mathematical characteristics of nonlinearities, together with their effect on accuracy of control system designs. The student will develop an understanding of a number of nonlinear phenomena such as limit cycles, jump resonance, subharmonic resonance, and the ability to include these characteristics into the design process.

IV. Required Background Experience

1. Basic understanding of classical control theory, including frequency response, Nyquist, root locus analysis, and design methods.
2. Modern control analysis and design techniques based on state space methods.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to nonlinear phenomena.	2 hrs
2. Root locus method for predicting limit cycles.	3 hrs
3. Frequency describing functions.	3 hrs
4. Prediction of limit cycles on the Nichols chart.	4 hrs

5. Lyapunov stability: analysis and design methods. 6 hrs
6. Design of compensation. 2 hrs
7. Introduction to phase plane/phase space singular points. 3 hrs
8. Isoclines, switch lines, dividing lines, eigenvectors. 3 hrs
9. Posicast control, bang-bang and sliding mode systems. 2 hrs
10. Time optimal control. 2 hrs
11. Chatter modes, sliding modes, curve following. 3 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be a least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The computer projects will be individual and they all aim at the application of optimal filtering and tracking techniques in a computer simulated environment. Topics of the projects will be as follows:

1. Sliding mode control of a missile with model uncertainties.
2. Minimum time control of a missile.
3. Tracking of a submarine using extended Kalman filter.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

All projects require the students to develop computer programs related to the theory developed in the lectures. Also, the students have to make educated choices between different design techniques and evaluate performances and trade offs.

Use of open ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade off of various techniques by computer simulations.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal control of physical systems. For each design problem the specifications will be given in line with commonly used engineering practice.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data

acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.
System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R. Cristi**
Date of Outline Preparation: **11/21/94**
Prepared by: **R. Cristi**
Revised:

EC4360 ADAPTIVE CONTROL SYSTEMS (3-1)

I. Catalog Description

This course addresses the problem of control systems which can self-adjust to changes in the operating conditions. Typical examples are autopilots for large ships which have to adapt to changes in load and/or sea conditions. Several techniques are presented, ranging from classical adaptive linear models to more modern techniques based on neural networks. PREREQUISITES: EC3310, EC3320.

II. Text and References

Notes from the instructor and selected articles from current literature.

III. Expected Outcomes

At the end of the course the student will be able to design a self-tuning control system operating in an uncertain environment, and evaluate its performance. In particular, the student will evaluate trade-offs in terms of performance and reliability of an adaptive system versus a control system design using conventional non-adaptive techniques.

IV. Required Background Experience

1. Basic understanding of classical and modern control theory, including analysis and design techniques based on state space methods.
2. Optimal recursive estimation using state space models.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Stochastic linear models for physical systems: AR, ARMA, state space, single input single output, multi-input multi-output.	6 hrs
2. Innovation models, predictors, optimal filters	3 hrs
3. Parameter estimation for AR models using Kalman filters: recursive least squares.	3 hrs

4. Parameter estimation for general linear models by extended Kalman filter. hrs
5. Parametric description of control systems: direct and indirect adaptive control. 3 hrs
6. On line identification and control of linear systems: techniques, stability, robustness. 6 hrs
7. Neural networks as models for nonlinear systems. hrs
8. Appication to adaptive control of nonlinear systems. hrs
9. Overview of existing adaptive systems. hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 20 to 30% of the final grade.

VI. Computer Usage

A number of class projects will be assigned as laboratory experiments. They all involve computer simulations of physical systems to be developed in MATLAB and/or SIMULINK.

VII. Laboratory

The computer projects will be individual, and their aim is to a) develop mathematical models for physical systems using data collected from experiments, and b) design, test, and evaluate adaptive control techniques from computer simulations. Topics of the projects will be as follows:

1. Model the dynamics of a small submersible vehicle from experimental data.
2. Design and test an adaptive controller for a system with uncertainties.
3. Evaluate the effects of disturbances and modeling errors on the stability of the adaptive system.
4. Design and test an adaptive controller using a neural network model.

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (45%) Design: 2 credit hrs (55%)

B. Design content

The projects in this class are all motivated by applications to engineering design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

All projects require the students to develop computer programs related to the theory developed in the lectures. Also, the students have to make educated choices between different design techniques and evaluate performances and trade-offs.

Formulation of design problem statements and specifications:

Each student is required to apply theoretically developed techniques to the design of optimal control of physical systems. For each design problem the specifications will be given in line with commonly used engineering practice.

Use of open-ended problems:

All problems presented are open ended and lend themselves to a number of optimal and suboptimal solutions. The student will be learning the trade-off of various techniques by computer simulations.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other

military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **2/6/95**
Prepared by: **C. W. Therrien**
Revised:

EC4400 ADVANCED TOPICS IN SIGNAL PROCESSING
(3-0)

I. Catalog Description

Special advanced topics in signal processing not currently covered in a regularly scheduled course and relevant to advanced naval and other military applications. Topics may include digital filter structures and implementations, advanced computational topics and architectures for signal processing, imaging, recent work in signal modeling, array processing, or other topics of interest. PREREQUISITE: EC3420 or consent of instructor.

II. Text and References

A suitable text may or may not be available; course may be taught from class notes and research papers.

III. Expected Outcomes

Knowledge of special advanced topics in digital signal processing currently not taught in existing courses. The course may be used by regular faculty members or visiting faculty with particular areas or expertise to present special new and interesting work.

IV. Required Background Experience

Dependent on topic at offering.

V. Detailed Description of the Course

A. Expanded Description of the Course

Dependent on topic at offering.

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam.

VI. Computer Usage

Dependent on topic at offering.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Varies, depending on topic.

B. Design Content

Dependent on topic at offering.

C. Design Attributes

Dependent on topic at offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **M. Tummala**
Date of Outline Preparation: **2/13/95**
Prepared by: **M. Tummala**
Revised:

EC4410 SPEECH SIGNAL PROCESSING (3-1)

I. Catalog Description

This course covers methods of digital signal processing as they are applied to speech communication for transmission, encryption, and recognition. The production and perception mechanisms are discussed. Topics include speech modeling analysis, synthesis, coding including LPC, and speech and speaker recognition. The techniques introduced here are also applied to sonar signal processing, voice controlled remote security and access, voice operated aircraft control, and other areas. PREREQUISITES: EC3400 and EC3420 or consent of instructor.

II. Text and References

Discrete-Time Processing of Speech Signals, J. R. Deller, J. G. Proakis, and J. H. L. Hansen, Macmillan, 1993.

III. Expected Outcomes

An understanding of production, modeling, analysis and synthesis of speech signals. A thorough knowledge of the techniques of processing short-time stationary signals, (short-time analysis) including short time Fourier analysis. Students learn to apply linear prediction theory in speech analysis, synthesis and coding. They also learn fundamentals of speech and speaker recognition techniques.

IV. Required Background Experience

1. Analysis of linear time-invariant digital signal processing systems:
   a. Difference equations.
   b. Frequency and z-domain analysis.
2. FIR and IIR filters.
3. Discrete Fourier transform and FFT.
4. Random processes (Preferably discrete-time version).
5. Signal and parameter estimation.
6. Autocorrelation function and power density spectrum.
7. Elementary matrix algebra.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Speech production, acoustic theory of speech production digital models for speech, and speech perception.	6 hrs
2. Short-time speech processing techniques, short-time autocorrelation, pitch period estimation, and short-time Fourier transform.	3 hrs
3. Speech coding techniques, waveform coding, ADPCM, vector quantization.	4 hrs
4. Linear predictive methods for speech, autocorrelation and covariance methods. LPC power spectrum, pitch detection, formant analysis, and LPC vocoders.	4 hrs
5. Speech synthesis, text-to-speech conversion.	7 hrs
6. Isolated word recognition, discussion of continuous speech recognition, selection of features for issues related to speaker recognition, and hidden worker models and neural networks for speech recognition.	3 hrs
7. Exams, holidays, and project presentations.	6 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction consists of lectures and computer demonstrations. Computer assignments are used to supplement the classroom lectures. A course project is required to be undertaken by each student. The lecture material is tested by using at least one midterm exam; usually, there is no final exam. Students present their course projects to the class and write a project report; peer evaluation of these projects is used. Projects typically account for 60% of the final grade.

VI. Computer Usage

Extensive use of MATLAB or C to develop various speech processing algorithms.

VII. Laboratory (including major items of equipment and instrumentation used)

Laboratory work consists of 5-6 assignments for speech conversion and processing. The PC based TMS320 systems or Sun workstations are used for speech digitization and processing, and MATLAB is used for developing algorithms.

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer assignments and the student selected course project involve design of digital filters -- both analog and digital. Design of systems for processing and analyzing speech sequences for use in speech recognition, compression, and speaker identification type of experiments is required as part of the course project.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Design of digital systems---digital filters, sample rate converters, median filters, thresholding devices---and their integration into systems for speech recognition, identification, verification, compression, and analysis/synthesis requires considerable creativity on the part of the student.

Use of open ended problems:

Course projects are generally based on open ended research problems. In the past some of the course projects have been presented (published) in professional conferences by the students.

Development and use of modern design theory and methodology:

The course material is continuously updated to include modern speech processing techniques. The course projects are based on the research problems reported in recent professional journals.

Feasibility considerations:

Feasibility of military applications for speech recognition, speaker verification, speech compression, and speech enhancement is considered in the course project.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
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Course Coordinator: **R. D. Hippenstiel**
Date of Outline Preparation: **2/6/95**
Prepared by: **R. D. Hippenstiel**
Revised:

EC4420 MODERN SPECTRAL ANALYSIS (3-1)

I. Catalog Description

Spectral estimation is the key to passive sonar detection, tracking, and identification. It also plays a dominant role in radar/sonar signature evaluation and in a majority of signal processing applications as they apply to the weapons technology of DOD. Classical and modern spectral estimation are developed from their basic ideas and compared in terms of performance and implementation. Topics covered are Fourier-based, model-based and eigenspace-based estimators, as well as Capon's method and Prony's method. Nonstationary spectral estimation schemes are discussed, in particular the Wigner-Ville distribution and the instantaneous power spectrum. Array processing is introduced from classical, model-based and eigenspace-based perspectives. Additional topics are cepstral analysis, higher order spectral estimators, and coherency. PREREQUISITES: EC3400 and EC3420.

II. Text and References

Modern Spectral Estimation, S.M. Kay, Prentice Hall, 1988.

or

Digital Spectral Analysis with Applications, S.L. Marple, Prentice-Hall, 1987.

III. Expected Outcomes

An understanding of the theoretical background of spectral estimation and experience with the experimental problems associated with this topic is the expected outcome. The lab projects introduce modern programming tools in the context of designing different spectral estimators.

IV. Required Background Experience

1. Random vectors and random processes.
2. Basic linear algebra.
3. Analysis of one-dimensional (1-D) linear time-invariant signal processing.
   a. Difference equations.

b. Convolution/correlation.
c. Frequency domain (z-domain) analysis.
d. Wiener filtering and linear prediction.
e. Modeling (AR, MA models).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of classical spectral estimators, and model based spectral estimators.	5 hrs
2. Topics in classical estimation: windows averaging cepstral analysis, etc.	3 hrs
3. Prony's method and Capon's (minimum variance) method.	3 hrs
4. Advanced topics: non-stationary spectral estimation higher order spectral estimators.	9 hrs
5. Eigenspace-based methods: Pisarenko, MUSIC, others.	6 hrs
6. Array processing: classical, parametric, Eigen subspace, and coherence.	5 hrs
7. Exams and holiday.	2 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture with project supported mode of instruction is used. The course will have at least one in class midterm and a final project take home final.

VI. Computer Usage

Five to seven mini-projects require computer use. Some homework results are complemented with computer results. Computer-based assignments are used to design algorithms to perform modeling and parameter (spectral) estimation. Some real data and simulated date is used. MATLAB and related toolboxes are used.

VII. Laboratory

Computer-based assignments are used to design algorithms to perform modeling and parameter (spectral) estimation. Some real data and simulated date is used. MATLAB and related toolboxes are used.

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The laboratory exercises are all project type labs and involve the design and performance analysis of spectral estimators.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student, on an individual basis, is required to participate in the design and evaluation of several spectral estimators.

Use of open ended problems:

Extra credit problems are used to extend the simulations and to expand the scope of the problems.

Formulation of design problem statements and specifications:

Each student is required to determine the specifications for his/her spectral estimation procedures.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications

systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **L. J. Ziomek**
Date of Outline Preparation: **2/21/95**
Prepared by: **L. J. Ziomek**
Revised:

EC4450 SONAR SYSTEMS ENGINEERING (4-1)

I. Catalog Description

Mathematical development and discussion of fundamental principles that pertain to the design and operation of passive and active sonar systems critical to naval operations. Topics from complex aperture theory, array theory, and signal processing are covered. This course supports the undersea warfare and engineering acoustics curricula and others. PREREQUISITES: EC3450 or PH3452 or PH3402 and either EC3410 or EC3500 or EO3402.

II. Text and References

Fundamentals of Acoustic Field Theory and Space-Time Signal Processing, L. J. Ziomek, CRC Press, Inc., 1995

III. Expected Outcomes

Knowledge of theoretical principles and concepts that govern the design and operation of passive and active sonar systems. In addition, awareness of the consequences and design tradeoffs associated with altering important sonar system parameters.

IV. Required Background Experience

1. Fundamentals of underwater sound propagation.
2. Fundamentals of communication theory including Fourier series and Fourier transform theory; and amplitude, phase, and frequency modulation.
3. Fundamentals of digital signal processing including the discrete Fourier transform.
4. Fundamentals of random processes including ensemble averages, correlation functions, and power spectral density functions.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Coupling transmitted and received electrical signals to the fluid medium: complex aperture functions.	1 hr
2.	Near-field and far-field directivity functions of volume apertures: three-dimensional spatial Fresnel and Fourier transforms.	3 hrs
3.	Linear apertures and far-field directivity functions: one-dimensional spatial Fourier transform; rectangular, triangular, cosine, Hanning, Hamming, and Blackman amplitude windows; 3-dB beamwidth; beam steering; beamwidth at an arbitrary tilt angle.	5.5 hrs
4.	Linear apetures and near-field directivity functions: one-dimensional spatial Fresnel transform; beam steering and aperture focusing.	1 hr
5.	Planar apertures and far-field directivity functions: two-dimensional spatial Fourier transform; beam steering; separable functions in rectangular and polar coordinates; rectangular and circular pistons; nth-order Hankel transform and Fourier-Bessel transform.	2.5 hrs
6.	Planar apertures and near-field directivity functions: two-dimensional spatial Fresnel transform; beam steering and aperture focusing.	0.5 hr
7.	Directivity index.	1.5 hrs
8.	Linear arrays and far-field directivity functions: one-dimensional discrete spatial Fourier transform; product theorem; amplitude weighting, the Dolph-Chebyshev method; the phased array (beam steering); far-field beam patterns and the discrete Fourier transform.	6 hrs
9.	Linear arrays and near-field directivity functions: beam steering and array focusing.	1 hr
10.	Array gain.	3 hrs
11.	Planar arrays and far-field directivity functions: two-dimensional discrete spatial Fourier transform; product theorem; concentric circular arrays; the phase array (beam steering).	2 hrs
12.	Planar arrays and near-field directivity functions: beam steering and array focusing.	0.5 hr
13.	Volume arrays and far-field directivity functions: cylindrical and spherical arrays of omnidirectional point elements.	1.5 hrs
14.	FFT beamforming for planar arrays: three-dimensional DFT, target signature analysis, estimation of angles of arrival.	3.5 hrs
15.	Complex envelopes: pre-envelope, analytic signal, Hilbert transform, complex envelope, envelope, amplitude and angle modulated carriers, instantaneous phase and frequency, phase and frequency modulation, quadrature demodulator, bandpass sampling theorem, signal energy.	2 hrs

16.	The auto-ambiguity function: binary hypothesis testing, parameter estimation, correlator receiver, signal-to-noise ratio (SNR), Neyman-Pearson test, probability of detection, probability of detection, probability of false alarm, time delay and Doppler shift estimates; the normalized auto-ambiguity functions of rectangular-envelope CW and LFM pulses, signal design, range, and Doppler resolution.	4.5 hrs
17.	Time compression/stretch factor, time delay, and Doppler-shift expressions: monostatic and bistatic geometries.	1 hr
18.	Holidays and exams.	4 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There are two one-hour exams, a final exam, and computer projects.

VI. Computer Usage

Computer projects on FFT beamforming are assigned. Students are free to choose whatever programming language and computer they want to use.

VII. Laboratory

The laboratory periods are devoted to computer projects.

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%)   Design: 2 credit hrs (45%)

B. Design Content

The majority of the theoretical derivations and examples worked out in class yield equations that are directly applicable to the real world design and operation of both passive and active sonar systems. In addition, the majority of the homework problems, as well as the computer projects, are practical, design oriented problems that yield numerical results so that the students can get "a feel for the numbers."

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Feasibility considerations:

Discussions in class are concerned with the issue of what is required in order to implement a certain feature or capability into a sonar system.

Realistic constraints on design:

This course provides the student with the awareness of the consequences and design tradeoffs associated with altering important sonar system parameters such as beamwidth, array gain, probability of detection, range and Doppler resolution, etc.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other

military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **M. Tummala**
Date of Outline Preparation: **4/13/95**
Prepared by: **M. Tummala**
Revised:

EC4460 ARTIFICIAL NEURAL NETWORKS (3-1)

I. Catalog Description

The basic theory and practice of artificial neural networks and their applications in electrical engineering are presented. Modeling of biological neurons as processing elements, their organization into a network of interconnected artificial neurons, and some basic laws of learning are discussed. Details of learning algorithms, such as LMS, backpropagation, self-organizing map, adaptive resonance theory and simulated annealing, are presented. Emphasis is placed on problems related to pattern recognition and classification, control systems, optimization, and data compression. Course projects address DOD specific applications, such as radar/sonar target recognition and classification using image or acoustic data. Genetic algorithms and fuzzy logic are introduced. PREREQUISITES: EC3500 or EC3410 and knowledge of simple electronic and logic circuits.

II. Text and References

Texts:

Neural Networks: A Comprehensive Foundation, S. Haykin, Macmillan, 1994.

Fuzzy Logic; Genetic Algorithms, notes.

References:

Neurocomputing, R. Heicht-Nielsen, Addison-Wesley, 1990.

Neural Networks for Optimization and Signal Processing, A. Cichocki and R. Unbehauen, John Wiley & Sons, 1993.

III. Expected Outcomes

Students gain an understanding of different artificial neural network architectures, several supervised and unsupervised learning principles, and a variety of problems that the neural networks are capable of handling (in a more efficient manner than the conventional computers). They acquire the capability to apply the neural network techniques to recognition, classification, optimization, and control-type problems; they receive some practice in application from the course project. They are exposed to some related emerging topics, such as fuzzy logic and genetic algorithms.

IV. Required Background Experience

1. Mathematical modeling of physical systems.
2. Linear system theory.
3. Differential and difference equations.
4. Basic knowledge of optimization techniques.
5. Random processes (discrete or continuous).
6. Basics of signal and parameter estimation.
7. Electronic circuits.
8. Basics of digital computer circuits and functioning.
9. Computer programming (C and MATLAB preferred).
10. Elementary matrix algebra.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. The model of artificial neurons based on biological neurons and their organization into a network of interconnected neurons; from a linear network to a neural network. The nonlinear transfer characteristic. Programmable computers versus neural networks.	2 hrs
2. Supervised and unsupervised learning. Learning laws of various types: Hebbian, gradient search (LMS), competitive, adaptive resonance theory (ART), and simulated annealing.	3 hrs
3. The perceptron. The perceptron learning law; convergence theorem. Single and multilayer perceptron architectures.	2 hrs
4. The backpropagation learning algorithm. Nonlinear mapping and neural networks. Delta rule and learning by backpropagation. Error surfaces and function approximation.	3 hrs
5. The bidirectional networks. Hopfield network; related analysis and models. Simulated annealing and the Boltzmann machine.	4 hrs
6. Self-organizing systems. Hebbian learning. Principal components analysis. The self-organizing feature-map algorithm. The adaptive resonance theory.	4 hrs
7. Emerging techniques. Genetic algorithms: basic concepts and some examples. Fuzzy logic: definitions, membership functions, fuzzy association, and application to the back-propagation learning.	5 hrs

8. Neural network applications in engineering. Pattern recognition (acoustic and image) and target classification. Control systems. Vision. Miscellaneous applications: financial, medical, credit rating, etc.		3 hrs
9. Project presentations.		4 hrs
10. Exams and holidays.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction consists of lectures and computer demonstrations. Computer assignments are used to supplement the classroom lectures. The lecture material is tested using at least one mid-term exam. Couputer assignments typically account for 20% of the final grade while the course project carries a 50% weight.

VI. Computer Usage

Computer demonstrations are used in the classroom to present the principles of learning algorithms. Computer project utilizing MATLAB or C are assigned:

1. The perceptron.
2. The LMS algorithm.
3. The multilayer perceptron using backpropagatin algorithm.
4. The Hoffman network.
5. The principal components analysis algorithm.
6. The competitive learning algorithm.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

The computer projects assigned in this course require design of neural models and their layered or recurrent structure. Also involved are design tasks such as data (acoustic/image) preconditioning and parameter extraction which require developing appropriate algorithms.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Design of learning algorithms and their application to a given problem, such as classification of objects or their recognition, or designing a nonlinear control system requires student creativity.

Use of open ended problems:

Course projects are generally based on open ended research problems taken from the current literature.

Development and use of modern design theory and methodology:

The course material is continuously updated to include recent developments in neural networks and fuzzy logic. The course projects are based on the research problems reported in recent professional journals.

Realistic constraints on design:

In their design projects, students learn the design trade-offs among the types of neural models used, the network architecture adopted, the learning algorithm selected to achieve the performance goal, the number of neurons in the implementation, and the number of computations required.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **M. Tummala**
Date of Outline Preparation: **2/15/95**
Prepared by: **M. Tummala**
Revised:

EC4470 ADAPTIVE SIGNAL PROCESSING (3-1)

I. Catalog Description

Introduction to the theory of adaptive signal processing for random sequences. Topics covered include: review of Wiener filters and one-step forward linear prediction-error filters; one-step backward linear prediction-error filters; analysis and synthesis lattice prediction-error filters; adaptive tapped-delay-line filters using steepest descent, least-mean-squares (LMS) and recursive least-squares (RLS) algorithms; and adaptive lattice filters. PREREQUISITE: EC3400 and EC 3420.

II. Text and References

Adaptive Filter Theory, 2nd Ed., S. Haykin, Prentice-Hall, 1991.

III. Expected Outcomes

The student learns the theory of adaptive signal processing of random sequences including the fundamentals of the steepest descent, least-mean-squares (LMS), and recursive least-squares (RLS) adaptive algorithms. In addition, the student gains an understanding of the fundamentals of adaptive lattice filters.

IV. Required Background Experience

1. Fundamentals of digital signal processing of random sequences.
2. Fundamentals of Wiener Filters.
3. Fundamentals of one-step forward linear prediction-error filters.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of Wiener filters and properties of autocorrelation matrices.	4 hrs
2. Review of one-step forward linear prediction-error filters.	2 hrs
3. One-step backward linear prediction-error filters, analysis and synthesis lattice prediction-error filters.	9 hrs

4. Adaptive tapped-delay-line filters using the steepest descent and LMS algorithms.		7 hrs
5. Adaptive tapped-delay-line filters using the RLS algorithm.		4 hrs
6. Adaptive lattice filters (stochastic GAL algorithm).		3 hrs
7. Holiday and mid-term exam.		4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction consists of lectures and computer demonstrations. Computer projects are required to be undertaken by each student. The lecture material is tested by using at least one midterm exam; usually, there is no final exam. A written project report of each computer project is required; sometimes, peer evaluation of these projects is used. Projects typically account for 60% of the final grade.

VI. Computer Usage

Computer projects using the LMS and RLS adaptive algorithms are assigned. Students are free to choose whatever programming language and computer they want to use.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

Computer projects involve design of time-varying coefficient digital filters. Adaptive systems are designed for processing of realtime signals (for example, speech or underwater acoustic signals).

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Design of addaptive digital filters and their application to a problem such as cancelling a narrowband interference in a wideband signal requires considerable creativity on the part of the student.

Use of open ended problems

Course projects are generally based on open ended research problems based on recently published journal articles.

Alternate solutions:

Course projects are aimed at providing alternate solutions to those existing in the literature.

Feasibility considerations:

Feasibility of military applications for systems based on adaptive filters is considered in the course projects.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **C-H. Lee**
Date of Outline Preparation: **02/9/95**
Prepared by: **C-H. Lee**
Revised:

EC4480 IMAGE PROCESSING AND RECOGNITION (3-2)

I. Catalog Description

This course provides image processing background for understanding modern military applications such as long range target selection, medium range identification, and short range guidance of new weapons systems. Subjects include image sampling and quantization, image representation, enhancement, transformation, encoding, and data compression. Predictive coding, transform coding, and interframe coding techniques are also introduced. Some effort is directed toward image compression techniques particularly suited for multimedia video conferencing. The course contains a series of experiments using special peripherals and computers. PREREQUISITE: EC3400

II. Text and References

Fundamentals of Digital Image Processing, A. K. Jain, Prentice-Hall 1989.

III. Expected Outcomes

A foundation and basic knowledge of image processing problems and techniques. Emphasis is given to mathematical and engineering concepts that are unique to image processing.

IV. Required Background Experience

1. Knowledge of discrete signals and systems.
2. Knowledge of the discrete Fourier transform.
3. Experience in programming in a high level language or MATLAB.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Two-dimensional systems and mathematical preliminary.	6 hrs
2. Image perception.	3 hrs

3. Image sampling and quantization. 4 hrs
4. Discrete Fourier transform properties of 2-D Fourier transform, cosine transform, and KL transform. 8 hrs
5. Image enhancement, histogram modification, image smoothing, image sharpening. 3 hrs
6. Image encoding, fidelity criteria, encoding process, error-free encoding. 6 hrs
7. Image representation by stochastic model. 4 hrs
8. Image data compression. 5 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture/laboratory method of instruction is used. There will be one midterm and one final exam. Homework and laboratory reports are also included in the evaluation.

VI. Computer Usage

Total dependence upon the use of the workstations in laboratory for image processing experiments (see below).

VII. Laboratory (including major items of equipment and instrumentation used)

Six laboratory exercises in image processing; Digital Image Display, Psychovision, Image Digitzation, Image Transforms, DPCM Coding of Images, Color/Gray Image Enhancement.
There also might be a special project. Sparc-10 workstations are used in the experiments.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

In this course a series of six laboratories are conducted by the students. Basic skills and knowledge learned from the book are practiced. The design content is largely gained from the six laboratory series and the possible final project.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are required to conceive and carry out a final project where skills learned in the laboratory sequences are practiced. Students create their own project where learned skills are demonstrated.

Formulation of design problem statement and specifications:

Students are required to turn in a project proposal where objective and scope of the work are formulated.

Consideration of alternative solution:

Students will explore possible solutions for the work. Tradeoffs between benefits and costs are considered. Decision on a particular solution is made by the student.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinators: **J. H. Miller**
& C-S. Chiu
Date of Outline Preparation: **2/17/95**
Prepared by: **J. H. Miller**
Revised:

EC4490 OCEAN ACOUSITC TOMOGRAPHY (3-0)

I. Catalog Description

An introduction to ocean acoustic tomography, an underwater acoustic inverse technique for mapping ocean sound speed and current fields. Covers the major aspects of ocean acoustic tomography, including the underlying concepts, the design and transmission of tomographic signals, and linear inverse methods for the reconstruction of ocean fields. PREREQUISITE: EC2410 or OC3260, or PH4453 or equivalent. Also offered as OC4490.

II. Text and References

Instructors' notes and journal articles.

III. Expected Outcomes

This is intended to be an elective, capstone course for electrical engineering students with an interest in acoustic signal processing, Engineering Acoustics, and Oceanography majors with an interest in underwater acoustics. Students acquire an understanding of the underwater acoustics, signal design and processing, and linear inverse theory used to image ocean features.

IV. Required Background Experience

1. Fourier transforms (EC2410 or OC3150).
2. Underwater acoustics (EC3450 or OC3260 or PH4453).
3. Linear algebra (desirable but not necessary) (MA3046).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to projections and tomography. 3 hrs
2. Ocean acoustics, the forward problem:
   a. Eigenray tracing and travel times. 2 hrs

b. Normal mode travel times.	2 hrs
c. Ambiguity analysis for ray/mode resolvability in time and frequency.	2 hrs
3. Tomographic signal design:	
a. Maximal length shift-register sequences and their correlation properties.	2 hrs
b. Acoustic signal phase modulation using maximal length sequences.	2 hrs
c. Replica correlation (matched filtering).	1 hr
d. Signal parameter design, amplitude, center frequency, bandwidth, angle modulation schemes.	2 hrs
4. Linear inverse methods:	
a. Continuous and discrete models.	2 hrs
b. Existence, uniqueness, construction and stability.	2 hrs
c. Backus-Gilbert, least squares, minimum variance.	2 hrs
d. Incorporation of a priori information.	1 hr
e. Resolution/variance tradeoff.	1 hr
f. Linearization of non-linear problems.	1 hr
5. Applications:	
a. Density tomography (one-way transmissions).	2 hrs
b. Current tomography (reciprocal transmissions).	2 hrs
c. Internal wave and surface wave tomography.	2 hrs
d. Augmenting the measurements: satellite radiometry, CTD, etc.	2 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

The method of instruction is a combination of lecture and small group interaction. Evaluation is made by grading four major design projects that cover the important technical issues in ocean acoustic tomography.

VI. Computer Usage

Three projects are to be assigned which will involve the use of the computer. The projects will involve MATLAB on the ECE or OC UNIX workstations.

1. CAT problem: In this project, you are given the projections of an unknown image and are asked to calculate the image.
2. Normal modes: In this project, you are asked to numerically calculate the acoustic normal modes of a given sound speed profile.
3. Arrival time estimation: You are given a acoustic signal time series in which is embedded is a tomography signal. Your job is to estimate the arrival time of that tomography signal.

VII. Laboratory

No formal laboratory.

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (50%) Design: 1.5 credit hrs (50%)

B. Design Content

Students design a Computer Assisted Tomography (CAT) machine in MATLAB software. The students are given only the projection of an unknown (to them) image and are asked to use the software CAT machine to estimate the image. The students are also asked to design a signal processing algorithm to decode ocean acoustic tomography signals. The algorithm is coded in MATLAB by the students. Actual underwater acoustic signals are given to the students and they are asked to demonstrate the effectiveness and efficiency of this algorithm design. Lectures are used to support and motivate the design projects.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Students are provided only a sketch of the algorithm for the computer problems. They are given design goals and data to test the software design.

Use of open ended problem:

In the CAT scan machine problem, the image is underdetermined. There are an infinite number of solutions that fit the data and an infinite number of algorithms to get the solutions. The students are asked how do they choose the best solution. In addition, the algorithms used are iterative and although solutions usually quickly converge, the students are asked when should they stop iterating.

Formulation of design problem statement and specifications:

The design problem statement is provided to the students along with algorithm specifications as a goal.

Consideration of alternate solutions:

The CAT problem can be solved in an infinite number of ways. The students are free to choose.

Feasibility consideration:

The algorithm outlined in the CAT problem as implemented by Hoursfeld won him a Nobel Prince in medicine. The algorithm outlined in the acoustic signal processing project has been implemented by a number of staff and students.

Realistic constraints on design:

Because computer resources are inherently limited, either in memory or speed, the algorithm implemented by the students in both projects are realistic.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

This course also supports the curriculum of Undersea Warfare (525), Air-Ocean (520), and the Combat Systems (533).

Naval Postgraduate School
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Monterey, California 93943-5121

Course Coordinator: **A. W. Lam**
Date of Outline Preparation: **2/6/95**
Prepared by: **A. W. Lam**
Revised:

EC4500 ADVANCED TOPICS IN COMMUNICATION (3-0)

I. Catalog Description

Topics and current developments in communications relevant to advanced naval and other military applications. Offered on an occasional basis with the topics determined by the instructor. PREREQUISITE: Consent of instructor.

II. Text and References

Class notes and research papers

III. Expected Outcomes

Knowledge of special advanced topics in communications currently not taught in existing courses. May be used by regular faculty members or visiting faculty with particular areas of expertise to present particularly new and interesting work.

IV. Required Background Experience

Dependent on topic at offering.

V. Detailed Description of the Course

A. Expanded Description of the Course

Dependent on topic at offering.

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam.

VI. Computer Usage

Homework and/or projects will be assigned that utilize MATLAB.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (65%) Design: 1 credit hr (35%)

B. Design Content

Dependent on topic at offering.

C. Design Attributes

Dependent on topic at offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESR for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **R. C. Robertson**
Date of Outline Preparation: **2/7/95**
Prepared by: **R. C. Robertson**
Revised:

EC4550 DIGITAL COMMUNICATIONS (4-0)

I. Catalog Description

This course presents the advantages and limitations of modern military M-ary digital communications systems. M-ary modulation formats, matched filter receivers, probability of error calculations, non-coherent receivers, carrier synchronization, symbol synchronization, telephone line modems, wideband modems, bandwidth and signal energy, diversity combining, and Rayleigh fading channels are covered. Examples of current operational and proposed military space and earth links are treated. PREREQUISITE: EC3510

II. Text and References

Digital Communications, 2nd ed., J. G. Proakis, McGraw-Hill, 1989.

III. Expected Outcomes

A qualitative and quantitative understanding of the performance characteristics of M-ary digital communication systems, and the capability to specify system parameters to achieve specified performance objectives. Capability to determine the sensitivity of alternate system realizations to common vagaries of propagation, implementation and interference, and to analyze the trade-offs among signal-to-noise ratio, error rate, information rate, bandwidth, complexity, and robustness.

IV. Required Background Experience

1. Fourier analysis and the relationship between the time-domain and frequency-domain.
2. Random variables and random processes; autocorrelation functions power spectral density, narrow-band random processes.
3. Conventional binary digital communication systems (BFSK, BPSK, ASK) and their performance in additive white Gaussian noise.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	M-ary signaling: symbols and bits, orthogonal symbol sets, signal constellations, Shannon's channel capacity theorem for band-limited, power-limited Gaussian channels.	2 hrs
2.	Optimum demodulators for M-ary signaling: correlation demodulators, matched filter demodulators.	2 hrs
3.	M-ary orthogonal signaling: coherent and non-coherent MFSK signals, receiver design, performance in AWGN, spectral efficiency, comparison with Shannon's channel capacity theorem.	7 hrs
4.	MPSK and M-DPSK: receiver design, performance in AWGN, spectral efficiency, comparison with MFSK, comparison with Shannon's channel capacity theorem.	5 hrs
5.	QAM: receiver design, performance in AWGN, spectral efficiency, comparison with MFSK and MPSK.	2 hrs
6.	Diversity: space, frequency, and time diversity, performance of MPSK and noncoherent MFSK diversity systems in AWGN.	2 hrs
7.	Digitally coded modulation: linear block codes and convolutional codes, soft and hard-decision decoding, probability of error, trellis-coded modulation for bandwidth-constrained channels.	6 hrs
8.	Fading channels: multipath, frequency selective and frequency non-selective channels, slow and fast fading channels, coherence time and coherence bandwidth of channel.	2 hrs
9.	Effect of fading on MPSK and non-coherent MFSK: performance of M-ary systems over Rayleigh fading channels with and without diversity.	5 hrs
10.	Carrier synchronization: suppressed carrier loops, Costas loops.	5 hrs
11.	Symbol synchronization: open-loop symbol synchronizers, delay-locked loop (early-late gate).	4 hrs
12.	Exams and holidays.	2 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam.

VI. Computer Usage

Homework and/or projects are assigned that utilize MATLAB and/or the SPC toolbox.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Students learn how to design an optimum digital communication system given the inherent trade offs in power, bandwidth, bit rate, and performance.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student must complete several digital system design projects.

Consideration of alternate solutions:

For each project, students must choose from a variety of both coherent and noncoherent M-ary systems to satisfy conflicting power, bandwidth, bit rate, and performance criteria.

X. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other

military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. C. Robertson**
Date of Outline Preparation: **2/7/95**
Prepared by: **R. C. Robertson**
Revised:

EC4560 COMMUNICATIONS ECCM (3-2)

I. Catalog Description

Methods of reducing the effects of hostile jamming on military radio communications systems are considered. Direct sequence spread spectrum systems and frequency-hopped spread spectrum systems are examined with regard to their LPI, LPD, and AJ capabilities. Time hopping and hybrid systems are also considered. Coarse and fine synchronization problems and techniques are presented. PREREQUISITE: EC3510.

II. Text and References

Principles of Secure Communication Systems, 2nd, ed., D. S. Torrieri, Artech House, 1992.

or

Introduction to Spread Spectrum Communications, R. L. Peterson, R. E. Ziemer, and D. E. Borth, Prentice-Hall, 1995.

III. Expected Outcomes

An understanding of the principal methods of communications ECCM and an understanding of the principles of the various forms of spread spectrum communication and systems performance in various forms of interference.

IV. Required Background Experience

1. Fourier analysis and the relationship between the time-domain and frequency-domain.
2. Random variables and random processes; autocorrelation functions, power spectral density, narrow-band random processes.
3. Conventional binary digital communication systems (BFSK, BPSK, ASK) and their performance in additive white Gaussian noise.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction: LPI, LPD, AJ (avoidance systems).	1 hr
2. Effect of interference on BPSK, BFSK: barrage jamming, pulse jamming, partial-band jamming, tone jamming.	2 hrs
3. Pseudo-Noise (PN) bodes: m-sequences, Gold codes, nonlinear codes.	2 hrs
4. Slow frequency-hopped BFSK: dehopping, transmission bandwidth, barrage jamming, multi-tone jamming, partial-message and partial-band jamming.	4 hrs
5. Fast frequency-hopped BFSK: barrage and partial-band jamming, perfect side information, noise-normalized BFSK receiver.	4 hrs
6. Direct-Sequence (DS) spread spectrum: signal spreading and de-spreading, transmission band-width, barrage jamming, single-tone jamming, pulse jamming, near-far problem, CDMA.	5 hrs
7. Code tracking: baseband Delay-Locked Loop (DLL), passband DLL, tau-dither loop.	3 hrs
8. Code acquisition: serial search techniques and acquisition using matched filters.	3 hrs
9. Time-hopping and hybrid systems.	1 hr
10. Interception and countermeasures: radiometer, cross correlator, channelized receiver, scanning superheterodyne receiver and other detection systems.	3 hrs
11. Cryptography : digital ciphers, public key systems, error probabilities.	3 hrs
12. Exams and holidays.	2 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There will be at least one exam plus a regularly scheduled final exam. Generally, laboratory work will constitute about 1/3 of the final grade.

VI. Computer Usage

Homework and/or projects are assigned that utilize MATLAB and/or the SPC toolbox.

VII. Laboratory

Working in groups of two, the students are asked to design, build, and test:

1. A circuit to generate an m-sequence.
2. A circuit to generate a frequency hopped signal and another circuit to dehop a hopping sinusoid.
3. A circuit to generate a direct sequence spread spectrum signal and another circuit to de-spread and demodulate the direct sequence signal.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%) Design: 2 credit hrs (50%)

B. Design Content

The laboratory exerciese in this class are all project type labs and involve the design of spread spectrum communication systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to participate in the design of a frequency-hopping BFSK spread spectrum system and a direct sequence/BPSK spread spectrum system.

Use of open ended problem:

The spread spectrum systems developed by the students are completely open ended except for the choice of code-sequence length.

Formulation of design problem statements and specifications:

Each student is required to determine the specifications for his/her system.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **R. D. Hippenstiel**
Date of Outline Preparation: **2/6/95**
Prepared by: **R. D. Hippenstiel**
Revised:

EC4570 SIGNAL DETECTION AND ESTIMATION (4-0)

I. Catalog Description

Principles of optimal signal processing techniques for detecting signals in noise are considered. Topics include maximum likelihood, Bayes risk, Neyman-Pearson and min-max criteria and calculations of their associated error probabilities (ROC curves). Principles of maximum likelihood, Bayes cost, minimum mean square error (MMSE), and maximum a posteriori estimators are introduced. Integral equations and the Karhunen-Loeve expansion are introduced. The estimator-correlator structure is derived. Emphasis is on dual development of continuous time and discrete time approaches, the latter being most suitable for digital signal processing implementations. This course provides students the necessary foundation to undertake research in military radar and sonar systems. PREREQUISITE: EC3410 or EC3500.

II. Text and References

Detection of Signals in Noise, Whalen, Academic Press, 1971.

Detection, Estimation, and Modulation Theory, Part I, V. Trees, 1968.

III. Expected Outcomes

A knowledge of the principles of detection theory and to an understanding of the various forms, trade-offs and implementation issues of various detection/estimation schemes.

IV. Required Background Experience

1. Probability theory, probability density functions.
2. Theory of random processes.
3. Correlation and spectral analysis of random processes.
4. Modulation -- analog and digital.
5. Linear algebra.
6. Linear systems theory.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Hypothesis testing (in particular Bayes, ML, MAP, Neyman Pearson, SLRT, min-max, and minimum probability of error criteria), composite hypothesis problems, nonparametric detection.	10 hrs
2. Performance evaluation in terms of false alarm, miss, and detection probabilities versus signal-to-noise ratio, ROC curves.	3 hrs
3. Continuous signals and the matched filter/correlator.	3 hrs
4. Orthogonal representations of signals and noise such as Fourier, Gram-Schmidt, Karhuenen-Loeve.	6 hrs
5. Integral equations.	3 hrs
6. Colored noise problems (pre-whitening, Fredholm equation).	3 hrs
7. Signals with unknown parameters.	3 hrs
8. Parameter estimation, definition of properties, Cramer-Rao bound.	3 hrs
9. Waveform filtering (i.e., Wiener, Kalman).	3 hrs
10. Spectral analysis via FFT and its relationship to detection/ estimation.	4 hrs
11. Exams and holidays.	3 hrs
TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture project supported mode of instruction is used. There will be at least one in class examination and final project take home test. The computer simulations constitute about one-third of the final grade.

VI. Computer Usage

Five to seven computer projects will be assigned that utilize MATLAB and/or the SPC toolbox.

VII. Laboratory

The students are asked to design, build, and test (via simulation):

1. A variety of detectors.
2. Test the performance by creating performance curves.

VIII. Accreditation

A. Science/Design Mix

Science: 3.5 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

The laboratory exercises in this class are all project type labs and involve the design of detection schemes.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to participate in the design of parametric and non-parametric detectors.

Use of open ended problems:

Extra credit problems are used to extend the simulation and expand the scope of the problems.

Formulation of design problem statements and specifications:

Each student is required to determine the specifications for his/her detection procedures.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **P. Moose**
Date of Outline Preparation: **6/6/95**
Prepared by: **P. Moose**
Revised:

EC4580 CODING AND INFORMATION THEORY (4-0)

I. Catalog Description

Digital military communication systems often employ error control coding to improve the effectiveness against noise, fading, and jamming. This course together with EC4560 provides students the necessary foundations for understanding the principles of such systems. Topics include concepts of information measure for discrete and continuous signals; fundamental theorems relating to coding and channel capacity; coding methods for error control in digital communications systems, convolutional, and block codes. Applications of the theory to real systems are discussed. PREREQUISITE: EC3410 or EC3500.

II. Text and References

Error Control Coding, S. Lin and D. J. Costello, Jr., Prentice-Hall, 1983

III. Expected Outcomes

Knowledge of concepts relating to information measures. An understanding of concepts of block and convolution codes, selection of proper codes for a given application, and evaluation of performance.

IV. Required Background Experience

Calculus, linear algebra, and background in basic communications principles.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Entropy and Shannon's first theorem.	2 hrs
2. Channel and mutual information channel capacity.	2 hrs
3. Shannon's main theories.	2 hrs
4. Huffman (variable length) codes.	2 hrs
5. Mathematicsl preliminaries.	8 hrs
6. Linear codes.	8 hrs

7. Cyclic codes.		8 hrs
8. Convolutional codes.		10 hrs
10. Examinations.		2 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

A lecture method of instruction is used. Homework assignments, midterm and final exam, design project are counted toward the final grade.

VI. Computer Usage

Assignment to implement and test an error control coding algorithm.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Each student is required to design a coder/decoder pair for forward error control.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Formulation of design problem statement and specifications:

Beginning with a channel description and a required throughput rate, maximum delay and maximum bit error rate for a communications link, the student must formulate a functional specification for forward error control coding for the link.

Consideration of alternate solutions:

The student must consider at least one block coding design and one convolutional coding design to meet the coding requirements. The relative advantages and disadvantages must be analyzed and a tradeoff matrix developed to compare the alternate solutions.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **T. T. Ha**
Date of Outline Preparation: **2/3/95**
Prepared by: **T. T. Ha**
Revised:

EC4590 COMMUNICATIONS SATELLITE SYSTEMS ENGINEERING (3-0)

I. Catalog Description

Communication satellite systems including the satellite and user terminals. Subjects include orbital mechanics, satellite description, earth terminals, detailed link analysis, frequency division multiple access, time division multiple access, demand assignment, random multiple access, and spread spectrum multiple access. Various military satellite communications systems are introduced. PREREQUISITE: EC3510 (may be concurrent).

II. Text and References

Digital Satellite Communications, 2nd Ed., T. T. Ha, McGraw-Hill, 1990.

III. Expected Outcomes

Knowledge of basic concepts of satellite communications. This includes acquiring expertise in making link calculations; an understanding of multiple access schemes used in satellite communications; and familiarity with several specific systems.

IV. Required Background Experience

1. Analog modulation: AM, FM.
2. Digital modulation: BPSK, BFSK.
3. Statistical analysis.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Overview of satellite systems: history, frequency band, satellite link, modulation, multiple access, interfaces.	1 hr
2. Orbital mechanics and satellite construction: orbital period, look angles, slant range, coverage, eclipse, launch, transponders.	3 hrs
3. Earth stations: antenna, power amplifier, up converter, low	3 hrs

noise amplifier, down converter, G/T figure of merit.

4. Link calculations: basic link, interference, rain attenuation, rain depolarization.	4 hrs
5. Frequeny division multiple access: FDM-FM-FDMA, SCPC, FM-FDMA television, interdemodulation.	4 hrs
6. Time division multiple access: frame, burst, superframe, efficiency, acquisition, synchronization, control and coordination of burst time plan, interfaces.	6 hrs
7. Efficient techniques: demand assignment, speech interpolation.	3 hrs
8. Random access: Aloha, reservation Aloha.	2 hrs
9. Spread spectrum multiple access: code division multiple access.	2 hrs
10. Military systems: jamming, antijamming.	2 hrs
11. Exams and holidays.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture mode of instruction is used. There will be one exam plus a regularly scheduled final exam.

VI. Computer Usage

Students are encouraged to do homework problems using MATLAB.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2 credits hrs (65%) Design: 1 credit hr (35%)

B. Design Content

Students learn to do detailed link analysis including interference, rain attenuation and depolarization. They also learn to design FDMA systems to reduce intermodulation effects and to improve efficiency in TDMA systems.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Student creativity:

Satellite systems are very complex. Students must learn through homework problems on how to include various real life conditions in the link analysis and multiple access design.

Use of open ended problem:

There are many ways to develop a link analysis. Students have complete freedom to come up with the one that meets the requirement.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Course Coordinator: **M. A. Morgan**
Date of Outline Preparation: **1/17/95**
Prepared by: **M. A. Morgan**
Revised:

EC4600 ADVANCED ELECTROMAGNETICS (3-0)

I. Catalog Description

An introduction is provided to advanced mathematical and numerical techniques of importance in the design and analysis of electromagnetic devices. Applications are considered for radar scattering, low observables, broad-band antennas, surface wave propagation, and microwave techniques. PREREQUISITE: EC3600, or equivalent, and consent of instructor.

II. Text and References

Advanced Engineering Electromagnetics, Balanis, Wiley, 1990.

III. Expected Outcomes

The objective of this course is to present currently employed methods for the analytical and numerical solutions of electromagnetic radiation, scattering and wave propagation problems.

IV. Required Background Experience

1. Vector calculus including differential and integral operations.
2. Partial differential equations including separation of variables.
3. Fourier and Laplace transform theory.
4. Computer programming experience in MATLAB or other high level language such as FORTRAN or C.
5. Working knowledge of fundamental concepts in electromagnetic theory.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of basic concepts in electromagnetics.	4 hrs
2. Solutions of initial-value and boundary-value problems.	3 hrs
3. Cylindrical and spherical harmonics applied to scattering.	6 hrs
4. High frequency approximations.	2 hrs

5. Green's functions and integral equations.	2 hrs
6. Numerical methods and linear function spaces.	3 hrs
7. Moment method solutions for thin-wire antennas and scatterers.	3 hrs
8. Variational principles applied to boundary value problems.	3 hrs
9. Finite difference and finite element methods.	4 hrs
10. Demonstrations and holidays.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-demonstration mode of instruction is used. Homework exercises requiring independent original work and computation are assigned every two weeks. These are graded and form 60% of the grade. A term project individually proposed by each student forms 40% of the grade.

VI. Computer Usage

Extensive computer exercises are employed to give experience in the various numerical methods covered in this course. Students write fundamental-level programs in MATLAB or other high level programming language using their choice of mainframe, workstation, or PC. Required programs include cylinder scattering (Bessel function routine provided), sphere scattering (spherical harmonic routines provided), thin-wire integral equation solution (matrix inversion routine provided), Helmholtz equation solution in 1-D and 2-D using finite differences and finite elements (matrix inversion routine provided), and time-domain finite difference solutions of the wave equation.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (70%) Design: 1 credit hr (30%)

B. Design Content

Graded homework exercises and the term project involve design of computer algorithms to evaluate the performance of electromagnetic systems such as antennas and radar targets.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student approaches the design of computer algorithms for complex electromagnetic computations on an individual basis.

Consideration of alternative solutions:

In many cases, especially in the term project, students are required to select from multiple possible techniques to design an optimal algorithmic approach.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Mathematics:

The officer will have a thorough knowledge of mathematical tools which are intrinsic to electrical and computer engineering, including, but not limited to differential equations, vector analysis, linear algebra, probability, numerical analysis, and Fourier and Laplace methods.

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

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Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **J. B. Knorr**
Date of Outline Preparation: **2/8/95**
Prepared by: **J. B. Knorr**
Revised:

EC4610 RADAR SYSTEMS (3-2)

I. Catalog Description

The radar range equation is developed in a form including signal integration, the effects of target cross section, fluctuations, and propagation losses. Modern techniques discussed include pulse compression frequency modulated radar, moving target indicator (MTI) and pulse Doppler systems, monopulse tracking systems, multiple unit steerable array radars, and synthetic aperture systems. Laboratory sessions deal with basic pulse radar systems from which the advanced techniques have developed, with pulse compression, and with the measurement of radar cross section of targets. PREREQUISITES: EC3410 or EC3500, EC3600, and either EC3610 or EC3630; U.S. citizenship and SECRET Clearance.

II. Text and References

Text:

Introduction To Radar Systems, M.I. Skolnik, 2nd Ed., McGraw-Hill, 1980.

Reference:

Principles of Modern Radar, Eaves & Reedy, VanNostrand, Reinhold, 1987.

III. Expected Outcomes

An understanding of basic radar theory by studying the radar range equation in its expanded form; a correlation of basic radar theory with the results obtained in the radar laboratory from transmitter, receiver, and radar cross-section measurements. A capability to design a basic radar system and predict its performance and to analyze systems utilizing modern concepts of synthetic aperture, track-while-scan and electronic steering.

IV. Required Background Experience

1. Properties of random time functions.

2. Statistical averages.
3. Autocorrelation and power spectral density.
4. Transform relations.
5. Noise models.
6. Antenna engineering.
7 Microwave engineering or radiowave propagation.

(EC4610 -- U.S. Citizenship and Secret Clearance Required)

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Pulse radar fundamentals: system functions (transmitter, receiver, antenna and indicator).	1 hr
2. Radar range equation: noise figure, matched filter probability of detection, probability of false alarm, target cross-section antenna parameters, system losses, propagation effects.	4 hrs
3. CW radar: Doppler effect, Doppler discrimination, range by FM-CW.	2 hrs
4. The clutter equation, clutter cross section, clutter resolution cell.	1 hr
5. MTI and pulse Doppler radar: delay line cancellers, blind speeds, clutter, improvement factor, range gates and filters, digital signal processing (FFT's) airborne systems.	5 hrs
6. Radar propagation: diffraction, reflection, refraction, ducting, attenuation.	1 hr
7. Tracking radar: conical scan, monopulse (amplitude and phase comparison) track-while-scan (ADT), Kalman filtering.	6 hrs
8. The ambiguity function: waveform design, knife edge, thumb-tack, bed of spikes classes of ambiguity diagrams.	2 hrs
9. Linear FM pulse compression: time-bandwidth products, matched filters (SAW devices), range sidelobe reduction.	2 hrs
10. Pseudo-random binary coded waveforms: Barker codes, linear maximal sequences, compression ratios.	3 hrs
11. Advanced topics: multiple unit steerable arrays, computer control, synthetic aperture; over-the-horizon (OTH) radars, bistatics; LPI (low probability of intercept) radars.	6 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory method of instruction is used. Student knowledge is evaluated on the basis of mid-term exams and a final exam.

VI. Computer Usage

Students are introduced to the computer program RGCALC.

VII. Laboratory (include major items of equipment and instrumentation used)

The laboratory goals are to develop an understanding of radar system performance by taking actual measurements of basic radar parameters and correlating these with classroom theory.

1. Select two lab radars such as AN/SPS-10 surface scan and MK-25 scan and MK-25 conical scan. Take measurements with appropriate instrumentation of peak power of transmitter, PRF, frequency spectrum of pulse noise bandwidth, noise figure and minimum discernible signal.	14 hrs
2. UPS-1 radar: take measurements of sub-clutter visibility and cancellation ratio.	1 hr
3. AN/SPS-40 radar: analyze coherent radar architecture measure compression ratio and processing gain.	6 hr
4. Calibrate MK 25 tracking radar: take measurement of RCS of standard non-fluctuat ing target; measure RCS of airborne targets of opportunity and compare them for different aspect angles with handbook tabular results. Measure clutter cross-section density of sea surface and rain (when possible).	1 hr

VIII. Accreditation

A. Science/Design Mix

Science: 3.5 credit hrs (85%) Design: 0.5 credit hr (15%)

B. Design Content

Some aspects of radar system design are covered in assigned homework problems.

C. Design Attribute

Development and use of modern design theory and methodology:

Students use theory covered in classroom lectures and computer software to solve homework problems with design content.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **J. B. Knorr**
Date of Outline Preparation: **2/8/95**
Prepared by: **J. B. Knorr**
Revised:

EC4620 RADAR SYSTEMS (3-2)

I. Catalog Description

This course covers essentially the same material as EC4610, but with deletions of detailed analysis of specific items. This course is intended for students who do not have U.S. citizenship. PREREQUISITES: EC3410 or EC3500, EC3600 or EO3602, and either EC3610 or EC3630.

II. Text and References

Text:

Introduction To Radar Systems, M.I. Skolnik, 2nd, Ed., McGraw-Hill, 1980.

Reference:

Principles of Modern Radar, Eaves & Reedy, Van Nostrand, Reinhold, 1987.

III. Expected Outcomes

An understanding of basic radar theory from studying the radar range equation in its expanded form; a correlation of basic radar theory with the results obtained in the radar laboratory from transmitter, receiver, and radar cross-section measurements. A capability to design a basic radar system and predict its performance and to analyze systems utilizing modern concepts of synthetic aperture, track-while-scan and electronic steering.

IV. Required Background Experience

1. Properties of random time functions.
2. Statistical averages.
3. Autocorrelation and power spectral density.
4. Transform relations.
5. Noise models.

6. Antenna engineering.
7. Microwave engineering or radiowave propagation.

V. Detailed Description of the Course

A. Expanded Description of the Course

1.	Radar fundamentals: system functions (transmitter, receiver, antenna and indicator).	1 hr
2.	Radar range equation: noise figure, matched filter probability of detection, probability of false, alarm target cross-section antenna parameters, system losses, propagation effects.	4 hrs
3.	CW radar: Doppler effect, Doppler discrimination, range by FM-CW.	2 hrs
4.	The clutter equation, clutter cross section, clutter resolution cell.	1 hr
5.	MTI and pulse Doppler radar: delay line canceller, blind speeds, clutter, improvement factor, range gates and filters, digital signal processing (FFT's) airborne systems.	5 hrs
6.	Radar propagation: diffraction, reflection, refraction, ducting, attenuation.	1 hr
7.	Tracking radar: conical scan, monopulse (amplitude and phase comparison) track-while-scan (ADT), Kalman filtering.	6 hrs
8.	The ambiguity function: waveform design, knife edge, thumb-tack, bed of spikes classes of ambiguity diagrams.	2 hrs
9.	Linear FM pulse compression: time-bandwidth products, matched filters (SAW devices), range sidelobe reduction.	2 hrs
10.	Pseudo-random binary coded waveforms: Barker codes, linear maximal sequences, compression ratios.	3 hrs
11.	Advanced topics: multiple unit steerable arrays, computer control, synthetic aperture; over-the-horizon (OTH) radars, bistatics; LPI (low probability of intercept) radars.	6 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory method of instruction is used. Student knowledge is evaluated on the basis of mid-term exams and a final exam.

VI. Computer Usage

Students are introduced to the computer program RGCALC.

VII. Laboratory

The laboratory goals are to develop an understanding of radar system performance by taking actual measurements of basic radar parameters and correlating these with classroom theory.

1. Select two lab radars such as AN/SPS-10 surface scan and MK-25 conical scan. Take measurements with appropriate instrumentation of peak power of transmitter, PRF, frequency spectrum of pulse noise bandwidth, noise figure and minimum discernible signal.	14 hrs
2. UPS-1 Radar: Take measurements of sub-clutter visibility and cancellation ratio.	1 hr
3. AN/SPS-40 radar: Analyze coherent radar architecture measure compression ratio and processing gain.	6 hrs
4. Calibrate MK 25 Tracking Radar: Take measurement of RCS of standard non-fluctuat ing target; measure RCS of airborne targets of opportunity and compare them for different aspect angles with handbook tabular results. Measure clutter cross-section density of sea surface and rain (when possible).	1 hr

VIII. Accreditation

A. Science/Design Mix

Science: 3.5 credit hrs (85%)   Design: 0.5 credit hr (15%)

B. Design Content

Some aspects of radar system design are covered in assigned homework problems.

C. Design Attribute

Development of modern design theory and methodology:

Students use theory covered in classroom lectures and computer software to solve homework problems with design content.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **D. Jenn**
Date of Outline Preparation: **3/17/95**
Prepared by: **D. Jenn**
Revised by:

EC4630 RADAR CROSS SECTION PREDICTION AND REDUCTION (3-0)

I. Catalog Description

This course covers the design and engineering aspects of stealth and its impact on platform and sensor design. Signature prediction methods in the radar, infrared (IR), and laser frequency bands are discussed. Radar cross section (RCS) analysis methods include geometrical optics and diffraction theory, physical optics and the physical theory of diffraction, and numerical solutions to integral and differential equations. Prediction methods for IR and laser cross sections (LCS) are also introduced. Signature reduction by shaping, materials selection, and active and passive cancellation and applied to each frequency regime. The measurement of these cross sections is also covered. PREREQUISITE: EC3600 or consent of instructor.

II. Text and References

Radar Cross Section, 2nd Ed., Knott, Shaeffer and Tuley, Artech House, 1993.

III. Expected Outcomes

Knowledge of low-observable design concepts for various platforms and systems. Knowledge of the capabilities and limitations of modern prediction methods and computer modeling codes.

IV. Required Background Experience

1. Plane wave reflection and refraction.
2. Transmission line analysis and impedance matching.
3. Basic antenna analysis methods.
4. Basic radiowave propagation concepts.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of radiation and scattering concepts and theorems.		4 hrs
2. Survey of computer codes.		3 hrs
3. Physical optics and impedance boundary conditions.		4 hrs
4. Numerical methods in the time and frequency domains.		5 hrs
5. Microwave optics.		4 hrs
6. IR signatures.		2 hrs
7. Laser cross section.		2 hrs
8. Modeling complex targets and reduction techniques.		5 hrs
9. Measurements.		2 hrs
10. Exams and review.		2 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

The course material is presented in lecture format. Grading is based on homework problems and a final project. A midterm exam is optional.

VI. Computer Usage

A survey of public domain RCS and LCS prediction codes is included in the course and their use required in homework assignments. Computer use is encouraged for solving homework problems that involve repeated calculations or the evaluation of tedious formulas.

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 1.5 credit hrs (50%) Design: 1.5credit hrs (50%)

B. Design Content

Both homework problems and the final project have design content. Homework problems involve tradeoffs between vehicle RCS and other performance measures such as aerodynamic efficiency, cost, and weight. Computer design and simulation are integrated into the homework problems. The final project, which is selected by the student from a range of approved topics, can also contain significant design.

C. Design Attributes

The design content of this course is distributed across the attibutes of design as follows:

Development of student creativity:

Creative and unique approaches to low observables is encouraged in the formulation and selection of the students' final project.

Development and use of modern design theory and methodology:

Students are required to apply the low RCS design principles introduced in lecture to the homework problems.

Forumulation of design problem statement and specifications:

The final project requires that each student select a problem and formulate the expected goals and outcome of their study.

Consideration of alternative solution:

Both the homework and the project encourage the student to examine unconventional approaches to the reduction of signatures.

Production processes/concurrent engineering/realistic constraints:

The limitations imposed by the manufacturing and assembly processes have a significant impact on RCS performance and are emphasized in homework. The cost and operational aspects of low observable vehicles are also presented.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications

systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

This course also supports the Electronic Warfare (595 and 596) curriculum: Electrical Engineering and Electronic Warfare; and Avionics (611): Electrical Engineering.

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Course Coordinator: **R. W. Adler**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. W. Adler**
Revised:

EC4660 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS ON COMMUNICATION SYSTEM PERFORMANCE (3-2)

I. Catalog Description

This course covers the effects of the electromagnetic environment on the performance of VLF-UHF land-based and shipboard communications systems with emphasis on SIGINT applications. Methods of evaluating system performance in the presence of electromagnetic interference (EMI) are discussed. Newly developed techniques that overcome shortcomings of classical EMI test procedures of locating and eliminating sources of EMI in order to improve system performance are demonstrated in the laboratory. Current research in non-classical propagation and antenna effects are covered. Computational tools for evaluating these effects are demonstrated. Students participate in a project by applying the test procedures and computer tools to a current military system or sub-system, gaining an appreciation for the impact of the EM environment on operational systems. PREREQUISITE: EC3650 or consent of the instructor.

II. Text and References

Introduction to Electromagnetic Compatibility, C. Paul, John Wiley, 1992.

High Frequency Communications; Science and Technology, J. Goodman, Van Nostrand Reinhold, 1992.

III. Expected Outcomes

Students learn the effects of the natural and man-made electromagnetic phenomena on military communication systems. They learn methods of identifying effects which can be controlled for the purpose of improving system performance and participate in a project related to a current military system.

IV. Required Background Experience

1. Basic radiowave propagation.

2. Basic antenna analysis.
3. Computational electromagnetic modeling techniques.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Review of radiation and propagation concepts.	2 hrs
2. The relationship between circuits and fields; RF coupling.	1 hr
3. Electromagnetic interference fundamentals.	2 hrs
4. Wideband and out-of-band component and system performance.	1 hr
5. EMI measurements and instrumentation.	2 hrs
6. Noise and interference in modern communication systems.	2 hrs
7. Unified barrier, filter and ground theory and practice.	2 hrs
8. Ionospheric and tropospheric propagation review.	2 hrs
9. High-latitude and equatorial ionospheric anomalies.	3 hrs
10. Target location and SIGINT applications.	2 hrs
11. System performance evaluation techniques.	2 hrs
12. Individual and team project coordination.	9 hrs
13. Midterm exam and project presentations.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There is one midterm exam given. The term project(s) are used in place of a final exam. Laboratory work constitutes about 25% of the final grade. The term project(s) constitute about 50% of the final grade.

VI. Computer Usage

A survey of military and public domain antenna and propagation prediction codes is included in the course and their use is required in homework and projects. Some of the codes used and developed in the prerequisite course are included.

VII. Laboratory

Use of the codes and demonstrations and use of the instrumentation discussed in the lectures is carried out in the laboratory sessions (two hours per week).

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%)   Design: 2 credit hrs (50%)

B. Design Content

The laboratory exercises are all project laboratories and are designed to measure performance and factors that degrade performance of systems. Software tools are used to analyze and predict the EM environment that impact the communication systems performance.

C. Design Attribute

Development of student creativity:

Each of the students is responsible for the identification of a problem associated with the system's performance. Using their knowledge of the expected or measured EM environment, they must apply the tools they have been provided and have learned about in order to evaluate the performance loss of the system. Then they must devise a mitigation approach which will restore system performance.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **P. E. Pace**
Date of Outline Preparation: **1/31/95**
Prepared by: **P. E. Pace**
Revised:

EC4680 RADAR ELECTRONIC WARFARE TECHNIQUES AND SYSTEMS (3-3)

I. Catalog Description

Radar electronic countermeasures and counter-countermeasures are considered in detail. Digital RF memories and directed energy weapons are also considered. Detailed sensor models are reviewed to solve analytically the effectiveness of various countermeasures. PREREQUISITES: EC4610 or EC3670, U.S. citizenship, and SECRET clearance.

II. Text and References

Radar Electronic Warfare, A. Golden, Jr., AIAA Education Series, 1987.

III. Expected Outcomes

This course is designed to acquaint the student with important new jammer hardware and techniques used to disable active RF sensors. The student will become familiar with various RF sensor models and also how to model the effects of countermeasures on the ability of these sensors to detect and track targets of interest. The student will also become familiar with important counter-countermeasures.

IV. Required Background Experience

1. SECRET clearance and US citizenship.
2. Radar systems.
3. Analysis of random signals.
4. Mathematics through calculus.
5. Antenna engineering.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Information warfare, command and control warfare. 2 hrs

2. Today's missiles. 2 hrs
3. Noise jammers. 3 hrs
4. Repeaters/transponders. 3 hrs
5. Self screening/standoff jamming. 3 hrs
6. Directed energy weapons. 3 hrs
7. Digital RF memories. 3 hrs
8. Counter-countermeasures. 3 hrs
9. Analytical models of tracking radars. 4 hrs
10. Modeling the effects of ECM on active radars. 7 hrs

TOTAL 33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There is one midterm and a regularly scheduled final exam or project. Laboratory work constitutes about one third of the grade.

VI. Computer Usage

Students use detailed computer models (e.g., AECM/IMOM/CTSView) to investigate the effectiveness of various countermeasures on active RF sensors.

VII. Laboratory

Study the design and operation of:

1. SLQ-32 (hardware).
2. Noise jamming (hardware).
3. AECM noise jamming (software).
4. AECM VGS/RGS (software).
5. IMOM mission survivability (software).
6. DLQ (hardware).
7. ULQ-21 (hardware).
8. CTSView active seeker against SSRM (software).
9. CTSView active seeker against RGPO/XPOL (software).
10. U-6 (hardware).
11. AECM advanced ECM techniques (software).

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%) Design: 2 credit hrs (45%)

B. Design Content

The laboratory exercise "Advanced ECM Techniques," involves the student designing an ECM suite to counter an RF sensor (which they also have to design). Also, the student designs various ECM waveforms analytically.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to design a RF sensor platform and an appropriate ECM suite to counter.

Development and use of modern design theory and methodology:

With knowledge of new state-of-the-art hardware, the student designs his/her own jammer waveforms and performs the appropriate analysis.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

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Course Coordinator: **P. E. Pace**
Date of Outline Preparation: **1/31/94**
Prepared by: **P. E. Pace**
Revised:

EC4690 RADAR ELECTRONIC WARFARE TECHNIQUES AND SYSTEMS (3-3)

I. Catalog Description

This course covers essentially the same material as EC4680. This course is intended for students who do not have U.S. citizenship. PREREQUISITES: EC4610 or EC3670.

II. Text and References

Radar Electronic Warfare, A. Golden, Jr., AIAA Education Series, 1987.

III. Expected Outcomes

This course is designed to acquaint the student with important new jammer hardware and techniques used to disable active RF sensors. The student will become familiar with various RF sensor models and also how to model the effects of countermeasures on the ability of these sensors to detect and track targets of interest. The student will also become familiar with important counter-countermeasures.

IV. Required Background Experience

1. Radar systems.
2. Analysis of random signals.
3. Mathematics through calculus.
4. Antenna engineering.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Information warfare, command and control warfare.	2 hrs
2. Today's missiles.	2 hrs
3. Noise jammers.	3 hrs
4. Repeaters/transponders.	3 hrs

5. Self screening/standoff jamming.		3 hrs
6. Directed energy weapons.		3 hrs
7. Digital RF memories.		3 hrs
8. Counter-countermeasures.		3 hrs
9. Analytical models of tracking radars.		4 hrs
10. Modeling the effects of ECM on active radars.		7 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-laboratory mode of instruction is used. There is one midterm and a regularly scheduled final exam. Laboratory work constitutes about one third of the grade.

VI. Computer Usage

Students use a detailed computer model (AECM) to investigate the effectiveness of various countermeasures on active RF sensors.

VII. Laboratory

Study the design and operation of

1. SLQ-32 (hardware).
2. Noise jamming (hardware).
3. AECM noise jamming (software).
4. AECM VGS/RGS (software).
5. DLQ (hardware).
6. U-6 (hardware).
7. AECM advanced ECM techniques (software).

VIII. Accreditation

A. Science/Design Mix

Science: 2.5 credit hrs (55%) Design: 2 credit hrs (45%)

B. Design Content

The laboratory exercise "Advanced ECM Techniques," involves the student designing an ECM suite to counter an RF sensor (which they also have to design). Also, the student designs various ECM waveforms analytically.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Each student is required to design a RF sensor platform and an appropriate ECM suite to counter.

Development and use of modern design theory and methodology:

With knowledge of new state-of-the-art hardware, the student designs his/her own jammer waveforms and performs the appropriate analysis.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **F. W. Terman**
Date of Outline Preparation: **2/28/95**
Prepared by: **F. W. Terman**
Revised:

EC4800 ADVANCED TOPICS IN COMPUTER ENGINEERING (3-0)

I. Catalog Description

Advanced topics and current developments in computer architecture including such subjects as: RISC vs. CISC; graphics processors relevant to naval and military applications and work stations, supercomputers and mini-supercomputers; computer structures for artificial intelligence; massively parallel architectures. PREREQUISITE: Consent of instructor.

II. Text and References

The text consists of handouts on current high-end processors from journal articles, conference proceedings, and processor manuals.

References:

1. *Advanced Microprocessors*, D. Tabak, McGraw-Hill, 1991.
2. *A Guide to RISC Microprocessors*, M. Slater, Ed., Academic Press, 1992.
3. *Computer Architecture: A Quantitative Approach*, D. A. Patterson and J. L. Hennessy, Morgan Kaufmann, 1990.

III. Expected Outcomes

In-depth familiarity with the latest high-end microprocessors. An understanding of the difference between general purpose and embedded applications of microprocessors.

IV. Required Background Experience

Familiarity with basic computer architectures and assembly language programming.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Caches, virtual memory, and floating point.		3 hrs
2. Motorola 68040 and 68060.		3 hrs
3. Intel i486.		2 hrs
4. Intel Pentium.		3 hrs
5. Introduction to RISC processors.		3 hrs
6. PowerPC architecture.		1 hr
7. PowerPC 601.		2 hrs
8. PowerPC 604.		2 hrs
9. SPARC architecture.		1 hr
10. Texas Instruments Super SPARC.		1 hr
11. Metaflow Thunder SPARC.		1 hr
12. Intel i860 XR and XP.		3 hrs
13. Introduction to embedded processors.		1 hr
14. Intel i960 family.		3 hrs
15. Midterms and holidays.		4 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction is by lectures and problem sets. The course grade is determined as follows: Midterms 45%, final exam 45%, and problem sets 10%.

VI. Computer Usage

None

VII. Laboratory

None

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (100%}

B. Design Content

This course explores the reasons behind various commercial designs of microprocessors, but does not require the students to do any design themselves.

C. Design Attributes

None

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
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Monterey, California 93943-5121

Course Coordinator: **D. J. Fouts**
Date of Outline Preparation: **2/13/95**
Prepared by: **D. J. Fouts**
Revised:

EC4810 FAULT TOLERANT COMPUTING (3-2)

I. Catalog Description

Introduction to fault-tolerant computing. The causes and effects of computer, digital system, and software failure. The fundamental concepts and techniques for the design and implementation of fault-tolerant computers, testing digital systems, and software. Modeling, simulation, and evaluation of fault-tolerant systems. Military and space applications of fault-tolerant computing. PREREQUISITES: EC3820 and EC3840.

II. Text and References

Text:

Design and Analysis of Fault Tolerant Digital Systems, B. W. Johnson., Addison-Wesley Publishing Company, Inc., 1989.

References:

1. *Reliable Computer Systems, Design and Evaluation*, 2nd Ed., D. P. Siewiorek and R. S. Swarz, Digital Press, 1992.

2. *Fault-Tolerant Computing, Theory and Techniques*, Vol. I and II, D. K. Pradhan, editor, Prentice-Hall, 1986.

III. Expected Outcome

The student will learn the fundamental concepts and techniques necessary to design, implement, manage, and procure high-reliability and high-availability computers, digital systems, and software. The student will also be prepared for advanced study in the area of fault-tolerant computing.

IV. Required Background Experience

Logic design, computer architecture, operating systems, computer programming (any language, assembly or high-level).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction, including goals, applications, and a brief history of fault-tolerant computing.	1 hr
2. Definitions, terminology, fault characteristics, and design philosophies.	2 hrs
3. Fault-tolerant design techniques, including hardware, information, time, and software redundancy.	9 hrs
4. Fault-tolerant software, including design, implementation, and testing techniques.	3 hrs
5. Evaluation techniques, including modeling, quantitative evaluation methods, and comparison techniques.	7 hrs
6. Practical fault-tolerant systems, including the design process, practical limitations, and real-world examples.	7 hrs
7. Exams, holidays, and miscellaneous.	4 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

The lectures cover the following chapters in the textbook: 1) Introduction, 2) Fundamental Definitions, 3) Design Techniques to Achieve Fault Tolerance, 10) Fault-Tolerant Software (from *Fault-Tolerant Computing, Theory and Techniques*), 4) Evaluation Techniques, and 5) The Design of Practical Fault-Tolerant Systems. Other material supplements the textbook at the discretion of the instructor. Homework and laboratory assignments on each chapter are made when the chapter is started in lecture. Homework assignments are not collected, but solution sets are handed out when lectures on a chapter are finished. Laboratory reports are due one week after lectures on a chapter are finished. Laboratory reports are graded and returned to the students. There is one midterm exam and one final exam. A final project is a significant part of the grade. Final projects usually take the form of hardware or software design projects, or detailed, in-class reports on actual fault-tolerant computing systems.

VI. Computer Usage

All students will need an account on the ECE department workstation network. Computer use will be approximately two hours per week.

VII. Laboratory

Laboratory work concentrates on computer modeling and simulation of various fault tolerant hardware and software techniques.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (75%) Design: 1 credit hr (25%)

B. Design Content

Computer architecture and logic design, fault-tolerant systems and software design.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Homework, laboratory assignments, and final projects require students to create original solutions to design problems.

Use of open ended problems:

Some homework problems, laboratory assignments, and final projects require iterative methods to obtain reasonable solutions to problems that have no optimal solutions.

Development and use of modern design theory and methodology:

All laboratory assignments utilize modern software tools and techniques for hardware design and simulation and software development.

Formulation of design problem statement and specifications:

Some laboratory assignments and final projects require students to formulate and specify a solution to a specific problem in fault-tolerant computing.

Consideration of alternative solutions:

Some laboratory assignments and final projects have no optimal solution and students must consider alternative solutions to obtain a practical answer.

Feasibility considerations:

An entire chapter of the book covers the feasibility and practicality of various different fault-tolerant computing techniques.

Detailed system descriptions:

Most final project topics require detailed descriptions of fault-tolerant computing systems.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

Naval Postgraduate School
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Course Coordinator: **F. W. Terman**
Date of Outline Preparation: **3/9/95**
Prepared by: **F. W. Terman**
Revised:

EC4820 ADVANCED COMPUTER ARCHITECTURES (3-1)

I. Catalog Description

A study of advances in computer architecture including computer description languages and memory system issues. High performance computers: pipeline supercomputers, array processors, multiprocessors. Data flow architectures and architectures for military applications. PREREQUISITES: EC3820, EC3840.

II. Text and References

Advanced Computer Architecture: Parallelism, Scalability, Programmability, Kai Hwang, McGraw-Hill, 1993.

III. Expected Outcomes

An understanding of the different approaches to building high performance computers and the various design issues and performance trade-offs in parallel processing. An understanding of how parallel computers can be used in practice.

IV. Required Background Experience

Introduction to modern processor architecture, operating systems, computer programming (any language, assembly or high-level).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction.	3 hrs
2. Parallel computer models.	3 hrs
3. Parallelizing compilers.	3 hrs
4. Program and network properties.	3 hrs
5. Principles of scalable performance.	3 hrs
6. Memory interleaving.	1 hr
7. Futurebus+.	4 hrs

8. Networks of workstations.		3 hrs
9. Multivector multicomputers.		3 hrs
10. SIMD computer organizations.		2 hrs
11. Project oral presentations.		3 hrs
12. Midterm and holidays.		3 hrs
	TOTAL	33 hrs

B. Method of Instruction and Evaluation

Instruction is by lectures, problem assignments, and the term project.

The course grade is determined as follows:

Midterm	25%
Final examination	40%
Term project	25%
Problem assignments	10%

VI. Computer Usage

None required, but some students may use the internet to obtain data for the term project. Other instructors have used the ECE workstation network for laboratory assignments.

VII. Laboratory

Laboratory time is devoted to the preparation of a paper on a subject chosen by the student with the instructor's approval. The chosen subject must be related to the course material, but not covered in the course lectures. An oral and a written report is presented by each student.

VIII. Accreditation

A. Science/Design Mix

Science: 3 credit hrs (85%) Design: 0.5 credit hrs (15%)

B. Design Content

Planning and researching the term project.

C. Design Attributes

Development of student creativity:

The laboratory project requires the student to choose an appropriate topic for investigation and to locate information about it in journals, in reports, on the internet, etc.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
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Course Coordinator: **H. Loomis**
Date of Outline Preparation: **5/1/94**
Prepared by: **H. Loomis**
Revised: **1/16/95**

EC4830 DIGITAL COMPUTER DESIGN (3-1)

I. Catalog Description

This course presents digital system design techniques that can be used in tactical embedded systems. It involves a study of the architecture of and the design process for digital computer systems. Topics covered include instruction set architectures, advanced computer arithmetic, hierarchical design techniques, and design of systems using standard and custom VLSI devices. Modern computer-aided design tools are emphasized. Laboratory project is the design of a digital computer. PREREQUISITES: EC3800 and EC3830.

II. Text and References

Text:

Computer Design and Architecture, L. H. Pollard, Prentice Hall, Englewood Cliffs, NJ, 1990.

References:

1. *Digital Circuits and Microprocessors*, H. Taub, McGraw-Hill, New York, 1982.
2. *Digital System Design Using VHDL*, C-H. Lee, CorralTek, Salinas, CA, 1992.
3. *Switching and Finite Automata Theory*, 2nd Ed., Z. Kohavi, McGraw-Hill, New York, 1978.
4. *Digital Design: Principles and Practices*, J. F. Wakerly, Prentice-Hall, Englewood Cliffs, NJ, 1990.

III. Expected Outcome

Understanding of the practice of hierarchical digital system design; knowledge of computer arithmetic, instruction set architecture and design; experience with the architecture and design of several classes of digital computers; and employment of this knowledge in a series of laboratory computer design projects.

IV. Required Background Experience

1. Switching circuit design, both combinatorial and sequential (EC2820, EC3830).
2. Computer data representation, including binary, octal, hexadecimal, and ones' and twos' complement number systems (EC2800, EC2820).
3. Microprocessor architecture (EC3800).
4. Experience with design entry and simulation CAD systems (EC3830).

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction.		1 hr
2. Numbers and codes.		1 hr
3. Arthmetic processors.		8 hrs
4. Asynchronous design.		4 hrs
5. Input/output bus design.		6 hrs
6. Memory design.		4 hrs
7. Pipeline systems.		6 hrs
8. The design projects.		11 hrs
9. Examinations and review.		3 hrs
	TOTAL	44 hrs

B. Method of Instruction and Evaluation

The course is organized into three one-hour lectures and a one-hour lab period per week. The lab is open format, i.e., students work on their projects on the Sun workstations on their own time.

Evaluation is obtained by two one-hour midterm exams and one two-hour final exam. The lab projects are also graded. Homework is assigned, but not graded. Solutions are made available.

VI. Computer Usage

Extensive use will be made of computer aided design tools, both via demonstrations to the class and as a part of the necessary design tools used for the system design project.

VII. Laboratory

Only 33 of the one-hour periods during the course will be allocated to lecture. The 11 hours allocated to the project will primarily be unscheduled group student work.

VIII. Accreditation

A. Science/Design Mix

Science: 1 credit hr (30%) Design: 2.5 credit hrs (70%)

B. Design Content

Techniques for computer-aided design of large, high-performance digital computers will be studied and applied to the design of a RISC register block and ALU in the project.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development and use of modern design theory and methodology:

Students will learn modern design theory of high-performance digital systems, and they will continue to use modern design theory and methodology and the computer-aided design tools for digital systems that they first experienced in the prerequisite EC 3830.

Formulation of design problem statement and specifications:

The students will develop a design problem statement and specifications for a pipeline register block, CACHE memory, and ALU for a RISC computer. They will then do the detailed design of the register block and test it. Next they will design the ALU and test it. Finally, they will integrate the register block and the ALU and test the subsystem.

Realistic constraints on design:

The criteria that they will design for are:

1. Proper functionality.
2. Pipeline throughput (clock rate).
3. Number of pipeline stages.
4. Efficiency of design in terms of number of gates and registers used.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Engineering Science and Design:

To acquire the requisite background needed to meet the other military education requirements, the officer will acquire proficiency in modern physics, electromagnetics, electronic devices and circuits, system theory, and modern electronic system design; also in other appropriate fields such as underwater acoustics, dynamics, fluid machanics and thermodynamics which provide the requisite breadth to a military engineering education.

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

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Course Coordinator: **S. B. Shukla**
Date of Outline Preparation: **06/94**
Prepared by: **S. B. Shukla**
Revised: **11/94**

EC4850 HIGH SPEED NETWORKING (3-2)

I. Catalog Description

The course objective is to develop an understanding of the emerging trends and technologies that enable deployment of high-speed global networks for tactical use. Coverage includes characterization of the networking requirements of multimedia DOD applications, ATM/SONET-based Gigabit network architectures, Gigabit LAN protocols, internals of TCP/IP and their viability in future high-speed internets, multicast protocols, and principles of mobile internet working including the DOD Common Data Link (CDL) and its interface to the terrestrial internet. The emphasis will be on network and transport layer functionality and evaluation of the bit rates visible to the end-users for a given network architecture specification. Network architectures and protocols will be evaluated in terms of the requirements of future command and control applications. PREREQUISITE: EC3850 or consent of the instructor.

II. Text and References

Text:

Data and Computer Communications, W. Stallings, 4th Ed., MacMillan.

References:

1. *Gigibit Networks*, C. Partridge, Addison Wesley, 1993.
2. *Asynchronous Transfer Mode: Solution for Broadband ISDN*, 2nd Ed., M. DePrycher, Prentice-Hall.

III. Expected Outcomes

This course is designed to give the student an understanding of the issues involved in building and operating the emerging integrated services wide-area real-time networks. A deep understanding of one aspect of these technologies is to be acquired as a result of the project/paper assignment.

IV. Required Background Experience

1. Probability theory.
2. Ability to program in a high level language, such as Ada or C.
3. The OSI reference model.
4. Local area networks.
5. Data link layer protocols and performance.
6. Packet switching.
7. The network layer functions.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Network and operating system interface.	3 hrs
2. Networking requirements of integrated multimedia applications.	3 hrs
3. Internal architecture of the TCP/IP internet.	3 hrs
4. Multicast over a TCP/IP internet.	3 hrs
5. Viability of TCP/IP for a global Gigabit network.	3 hrs
6. Transfer modes for Gigabit networks.	3 hrs
7. Asynchronous transfer mode (ATM)/Synchronous Optical Network (SONET).	3 hrs
8. Gigabit LAN protocols.	3 hrs
9. Internetworking over an ATM fabric.	3 hrs
10. Principles of mobile internetworking and the Common Data Link (CDL).	3 hrs
11. Exams and holidays.	3 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

A lecture-demonstration mode of instruction is used. The course will either have 1) at least two examinations or, 2) one examination and an extensive project/paper assignment.

VI. Computer Usage

A commercial network engineering CAD tools will be used for project-related and modeling and simulation.

VII. Laboratory

Assignments dealing with performance evaluation will be given as an option for the project. These assignments will involve building and evaluating network models using a commercial network engineering CAD tool, such as OPNET by MIL3, Inc. running on the ECE LAN. The initial laboratory periods will used to provide a tutorial for the C language/OPNET. The paper assignment will involve writing a thorough technical paper about the topics suggested and negotiated with the instructor.

VIII. Accreditation

A. Science/Design Mix

Science: 2 credit hrs (50%)   Design: 2 credit hrs (50%)

B. Design Content

In case of project, the students use a network engineering tool for designing a network subsystems, such as a LAN, a link, or a subnetwork. They are required to analyze this design for acceptable performance/functionality, thus validating it. In the case of a paper, they are required to design a solution to part of a research problem identified by the instructor and justify their design. Students are premitted to work in pairs or alone.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Within the overall scope and goal of the paper/project defined by the instructor, students define the detailed steps to achieve the goal.

Development and use of modern design theory and methodology:

This design attribute is applicable to project assignments. Students use the methods involved in modern simulation techniques, network engineering, and hierarchical structure of complex networks.

Formulation of design problem statement and specifications:

In this advanced-level course, each team is expected to possess sufficient background to state the problem categorically. The instructor provides the feedback about suitability and technical complexity. It is made clear to the students at the start that precision and thoroughness of the report is as important as the work itself.

Consideration of alternative solutions:

This design attribute is applicable to research papers. A comparative evaluation of existing approaches or multiple proposals developed by the student is emphasized.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **D. J. Fouts**
Date of Outline Preparation: **1/12/95**
Prepared by: **D. J. Fouts**
Revised:

EC 4870 VLSI SYSTEMS DESIGN (3-2)

I. Catalog Description

Introduction to the design and implementation of Complementary Metal Oxide Semiconductor (CMOS) Very Large Scale Integration (VLSI) digital Integrated Circuits (ICs). Topics covered include the specification of the high-level functional design, the design, implementation, and simulation of low-level cells, floor planning and the assemply of low-level cells into the high-level design using hierarchial place-and-route techniques, circuit extraction and simulation for functional verification and timing analysis, and the principles of CMOS IC fabrication. Applications of VLSI ICs in military systems are also covered. The course is centered around laboratory projects where student groups design, implement, simulate, and submit for fabrications, a full-custom CMOS, VLSI IC. IC functionality is selected by each student group. PREREQUISITES: EC3800 and EC3830.

II. Text and References

Principles of CMOS VLSI Design, 2nd Ed., Weste and Eshraghian, Addison-Wesley, 1992.

III. Expected Outcomes

The student will learn the techniques necessary to design and implement full-custom or semi-custom CMOS VLSI digital ICs, or manage a project involving the design and implementation of full-custom or semi-custom CMOS VLSI digital ICs. The fundamental concepts necessary for advanced study in the field of VLSI will be learned. The student will also gain first-hand knowledge of the use and availability of CAD tools for VLSI design, implementation, analysis, and simulation.

IV. Required Background Experience

1. Logic design.
2. Computer organization.

V. Detailed Description of the Course

A. Expanded Description of the Course

1. Introduction to silicon MOS transistors, CMOS logic circuits, and a brief history of VLSI.	3 hrs
2. Theory and operation of Si MOS transistors including terminal I-V characteristics and simulation methods, theory and operation of static CMOS, pseudo-nMOS, and pass-gate logic circuits, including noise-margin analysis and circuit simulation methods.	5 hrs
3. Wafer production and CMOS and BiCMOS processing techniques, layout rules, and techniques for preventing latch up.	4 hrs
4. Resistance and capacitance estimation, lumped and distributed RC effects, signal conductor routing, power conductor routing and sizing, gate switching characteristics and delay models, interconnect delay estimation, power consumption estimation, process scaling, and packaging issues.	7 hrs
5. CMOS logic circuits, including static, dynamic, domino, and others, transistor sizing, layout structures and techniques including sea-of-gates, PLAs, and finite state machines, clocking strategies and skew, pad drivers and receivers, and static protection.	9 hrs
6. Field trip to commercial foundry and clean room tour.	1 hr
7. Exams, holidays, and miscellaneous.	4 hrs
TOTAL	33 hrs

B. Method of Instruction and Evaluation

The lectures cover the following chapters in the textbook: 1) Introduction to CMOS Circuits, 2) MOS Transistor Theory, 3) CMOS Processing Technology, 4) Circuit Characterization and Performance Estimation, 5) CMOS Circuit and Logic Design. Other material supplements the textbook at the discretion of the instructor. Homework assignments on each chapter are made when the chapter is started in lecture. Homework assignments are not collected, but solution sets are handed out when lectures on a chapter are finished. Laboratory assignments are made periodically during the quarter. Laboratory reports are collected, graded, and returned to the students. The final laboratory project is graded separately. There is one midterm exam and one final exam.

VI. Computer Usage

All students will need an account on the ECE department workstation network. Workstation use will be approximately 4 hours per week.

VII. Laboratory

Laboratory assignments utilize an integrated set of advanced CAD tools for designing, implementing, and simulating CMOS VLSI ICs. Initial assignments familiarize students with the CAD tool set and design methods. During the later half of the quarter, student groups utilize the knowledge gained during the first half of the quarter to design, implement, simulate, and submit for fabrication, CMOS VLSI ICs. IC functionality is selected by each student group.

VIII. Accreditation

A. Science/Design Mix

Science: 1 credit hr (25%) Design: 3 credit hrs (75%)

B. Design Content

Functional specification and high-level IC design, logic design, circuit design, IC mask design, design of testing and evaluation procedures.

C. Design Attributes

The design content of this course is distributed across the attributes of design as follows:

Development of student creativity:

Laboratory final project requires students to be creative at all phases of IC development from coming up with the initial functional specification to the final testing and evaluation procedure.

Use of open ended problems:

The final project, as well as a couple of the early laboratory assignments, have multiple solutions and require an iterative process to arrive at a reasonable solution that cannot be proven to be optimal.

Development and use of modern design theory and methodology:

All of the laboratory assignments, especially the final project, emphasize modern VSLI design techniques and CAD tools.

Formulation of design problem statement and specifications:

The laboratory final project requires the student to identify a problem which can be solved with the application of a VLSI IC, and to create the functional specification for a chip that will solve the problem.

Consideration of alternative solution:

For the final laboratory project, students are required to consider alternative solutions at every phase of the design of their ICs. Students are also required to consider alternative solutions during aboratory assignments.

Feasibility considerations:

For the final projects, a limit is placed on the size of finished ICs, and actual foundry transistor parameters are used during design, requiring students to design their projects within real-world constraints.

Detailed system descriptions:

A detailed system description is an integral part of the initial phase of thefinal laboratory projects.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Computers:

The officer will have a sound understanding of computer hardware, software, and their integration into military systems including programming in higher order languages, digital logic circuits, and microprocessor applications.

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and
Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **C. W. Therrien**
Date of Outline Preparation: **5/19/95**
Prepared by: **C. W. Therrien**
Revised:

EC4900 SPECIAL TOPICS IN ELECTRICAL ENGINEERING (0-8)

I. Catalog Description

Supervised study in selected areas of electrical engineering to meet the needs of the individual student. A written report is required at the end of the quarter. PREREQUISITE: Consent of the department chairman. Graded on Pass/Fail basis only.

II. Text and References

Depends on instructor and/or course content.

III. Expected Outcomes

Familiarization of advanced topics of current interest in electrical engineering.

IV. Required Background Experience

Varying according to the instructor and the content of the course. Prerequisites of EC courses at the 3000 level are usually expected.

V. Detailed Description of the Course

A. Expanded Description of the Course

The content of this course will vary according to the topic.

B. Method of Instruction and Evaluation

According to the content, along the lines of regularly scheduled 4000 level courses in the ECE Department.

VI. Computer Usage

Although the course topics vary, assignments will be designed towards computer-aided analysis, a design, and/or the development of computer algorithms to support the material covered in class. Students use MATLAB or specialized software in computer aided design problems.

VII. Laboratory

According to topic.

IX. Accreditation

A. Science/Design Mix

Variable, according to topic, instructor.

B. Design Content

Variable.

C. Design Attributes

Variable, depends on course offering.

IX. Educational Skill Requirements (ESRs)

This course supports the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data

acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

Naval Postgraduate School
Department of Electrical and Computer Engineering
Monterey, California 93943-5121

Course Coordinator: **R. Cristi**
Date of Outline Preparation: **5/15/95**
Prepared by: **R. Cristi**
Revised:

EC4910-4990 SPECIAL TOPICS IN ELECTRICAL ENGINEERING (V)

I. Catalog Description

Courses on special and advanced topics in Electrical Engineering are developed under these headings. In most cases new courses are offered as special topics of current interest with the possibility of being developed as regular courses.

II. Text and References

Depends on instructor and/or course content.

III. Expected Outcomes

Familiarization of advanced topics of current interest in electrical engineering.

IV. Required Background Experience

Varrying according to the instructor and the content of the course. Prerequisites of EC courses at the 3000 level are usually expected.

V. Detailed Description of the Course

A. Expanded Description of the Course

The content of this course will vary according to the topic.

B. Method of Instruction and Evaluation

According to the content, along the lines of regularly scheduled 4000 level courses in the ECE Department.

VI. Computer Usage

Although the course topics vary, assignments will be designed towards computer-aided analysis, a design, and/or the development of computer algorithms to support the material covered in class. Students use MATLAB or specialized software in computer aided design problems.

VII. Laboratory

According to the topic.

VIII. Accreditation

A. Science/Design Mix

Variable, according to topic, instructor.

B. Design Content

Variable.

C. Design Attributes

Variable, depends on particular offering.

IX. Educational Skill Requirements (ESRs)

This course the following ESRs for curriculum 590:

Electronic and Electrical Engineering:

In order to provide officers skilled in the application of electronic systems to military needs, the officer will have competence in the broad area of electrical engineering including circuits, electronics, fiber optics, computer communications networks, and systems analysis. The officer will select elective courses to obtain breadth in his/her understanding of military electronic systems. Additionally, to achieve depth of understanding, the officer shall specialize in one of the following areas: (a) communications systems as applied to electronic counter countermeasures, low probability of intercept systems, low probability of detection systems, and other military issues; (b) guidance, navigation, and control systems; (c) radar, electro-optic, and electronic warfare systems; (d) high performance computer systems including advanced integrated circuits, parallel and distributed systems, and reliable real-time military platforms; (e) signal processing systems as applied to surveillance, underwater acoustic data acquisition and processing, imaging and target location, and other military issues; (f) total ship systems power engineering.

System Design and Synthesis:

The officer will have a sound understanding of engineering principles utilized in engineering system design, particularly as they relate to military systems, including establishment of system-related objectives and criteria.

XIII. LABORATORY FACILITIES

A. Summary of Facilities

See Table XV.

B. Assessment of Equipment

The Electrical Engineering Department equipment inventory value is approximately eight million dollars. This includes radar and military systems, computers, specialized equipment, general purpose electronic test equipment, and office equipment. The condition of this equipment ranges from good to excellent with the average being very good.

Large amounts of obsolete laboratory equipment have been excessed through the Defense Excess Property Program. One technician is responsible for inventory control and disposal of equipment. The Department has a continuous program to identify and remove obsolete equipment from our custody.

The Department's basic laboratory instruments are in excellent condition. During the past few years various laboratories have been reviewed and those with the greatest need and highest priority have been updated with new equipment. These laboratories include the Academic Computing Facilities, Radar Lab, the Microprocessor Lab, and the Controls Lab.

The larger military systems and equipment are maintained in good condition because of the high competence of Department technicians. They are generally older equipment that have been modified for pedagogical purposes, but still are adequate for instruction of basic principles. (In fact some of the older analog systems are better for instructional purpose than the newer digital counterparts since the signals are more easily seen and identified.) However, some of the more modern principles cannot be demonstrated with this equipment because of its limited capabilities.

C. New Equipment and Instrumentation installed in each laboratory since last visit

Equipment and instrumentation acquired by the ECE Department since 1989 are summarized below. Total amounts spent for equipment and instrumentation during this period are indicated in parenthesis for each lab. Also, the costs of very expensive single items are indicated.

Antenna Laboratory ($350K). The indoor antenna range (Microwave Anechoic Chamber, SP604) was completely refurbished with new microwave (X-band) absorber and a new antenna positioning/data acquisition system. New system employs a highly accurate stepper motor for antenna positioning and signal control/acquisition control performed by a 386 PC using Labview graphical based programming. Antenna pattern plots are printed via laser printer or can be stored to floppy disk.

The outdoor antenna range (SP703) has received a number of slightly used calibration antennae from military bases under closure. A new satellite TV antenna (10ft dish) and receiver system was installed providing for instruction, research, and video teleconferencing with C and Ku band reception. A new PC controlled amateur satellite (AMSAT) communication system has been installed in association with faculty research into signal propagation. Refurbishment plans for the existing antique outdoor RF antenna pattern measurement facility are underway.

Microwave Laboratory ($425K). A HP8510C Vector network analyzer with S parameter test set and a Micromanipulator, Microwave (MMIC)/Optical circuit probe station were procured for the lab. Probe station includes a microscope with video camera for detailed inspections of microwave and

Secure Computer Processing Laboratory ($312K). Major acquisition of five compatible Pcs with 30 removable harddrives ($20K). One Tempest SUNSparc 1+ computer system ($30K) with the Air Force Modeling and Simulation Program, Improved-Many-On-Many (IMOM) software installed ($27K). One SUNSparc 5 computer system ($15K) with the Air Force Modeling System for Advanced Investigation of Countermeasures (MOSAIC) software installed ($170K). Two additional computer systems reside in this lab for research use only ($50K).

D. Critical laboratory needs and plans for satisfying these needs

Critical laboratory needs include:

A method to reliably fund the replacement of obsolescent equipment. Most of our laboratory equipment has a very short lifetime, on the order of five years, being replaced by more capable, more reliable, and often lower cost units. With an inventory that has an approximate value of $8,000,000. even a ten year replacement period would require $800,000 per year! Yet our average new equipment budget has been about $200,000.

E. Plans for continual updating and development of laboratories

The updating and development is closely tied into the NPS budget formulation cycle. The following is a brief description of the budget and planning cycle as implemented at NPS.

The planning cycle for updating and developing laboratories is part of the School's general budgeting cycle. Long range plans (three to five years in the future) are made in the Program Objective Memorandum (POM) process. The Department identifies long-range laboratory and equipment plans to the Dean of Science and Engineering, who prioritizes and incorporates the plans into the School's annual preparation of the POM.

As the annual POM comes to within two or three years of implementation, the School receives budget guidance on the expectations of funding levels. Priorities are set within the Department and Division and the lists of requirements are updated for each year.

In the budget execution year the budget is allocated and executed by the Department. Adjustments in funding levels occur and equipment purchases are made or deferred, as appropriate.

The Department plans and priorities are set by the Department Committee on Laboratories and Facilities and the Chairman. The Committee solicits requests for lab space and equipment and prioritizes the requests.. The requests are formulated into a Department lab plan. The items in the plan are incorporated into an annual planning document submitted by the Chairman. This document includes request for operating funds for the following year (used for purchases of equipment up to $15,000 each, as well as maintenance and supplies), requests for identified large equipment purchases (greater than $15,000) for the next three years, and construction requests for space modifications.

Specific plans for the laboratory development are contained in the Department's lab plan and are briefly discussed in Section D above.

F. Provisions for maintaining and servicing laboratory equipment

Maintenance and servicing of laboratory equipment is done through various means including self-servicing and manufacturer repairs.

Maintenance contracts: We currently have no maintenance contracts on any of our lab or computer equipment.

Self-service: Minor maintenance (e.g., replacement of fuses, replacement of power supply modules, circuit board replacement, etc.) is done at the laboratory level by the lab technicians.

The Department also has a Calibration and Repair laboratory staffed by two civilian and one military calibration and repair specialists. We are able to calibrate, diagnose, and repair most items of general test equipment up to about one GHz. Above that frequency, most repairs are done by the manufacturer (for repairs beyond the obvious, such as replacement of a power supply).

Manufacturer repair: Items that our technician staff is unable to repair or calibrate are returned to the manufacturer using department operating funds.

TABLE XV
LABORATORY FACILITIES
Program Naval Postgraduate School MSEE

Facility (Bldg. & Rm. No.)	Purpose of Laboratory	Condition of Laboratory	Adequacy for Instruction	No. of Stations	Area (sq. ft.)
Material Support (Bu-108, 109, 212, 215, 216)	Maintenance Lab, Equipment Pool, Electronic Parts Issue.	Very Good	Very Good – provides material and equipment support for all departmental laboratories.	None	4908
Transient Electromagnetics (Sp-535)	Research in Transient Electromagnetic Scattering.	Good	Set up for thesis instruction & research. Equipment is well maintained.	4	1450
Radar (Sp-543, 543A, 545, 704)	Radar instruction.	Good	Adequate for principles and basics. Inadequate for modern concepts such as digital signal processing.	13	5418
Electronic Warfare (Sp-612, 616)	Study of Electonic Countermeasure (ECM) and Electronic Support Measures (ESM).	Good	Adequate – older model ECM equipment. New ESM equipment from lab upgrade.	14	864
Antenna (Sp-703, 703B)	Instruction, research, design, fabrication, and testing of antennas from VLF to microwave frequencies.	Fair	Good – Principles of antennas (via pattern measurement) are taught. Indoor range is modern anechoic chamber for x-band. Outdoor range has very old equipment but useable.	2	1500
Digital Systems (Bu-201)	Develop design approaches for microprocessors in systems, present trends in digital systems.	Very good	Very Good – Uses modern computers and logic analyzers.	42	1197
Electronic Circuits & Signals (Bu-201)	Electonics and circuits/signals laboratory.	Excellent	Very Good – Modern equipment & facilities.	41	6929
Servo/Controls Lab (Bu-208)	Illustrates techniques of control systems which apply to Navy tracking & fire control systems.	Very Good	Very Good – Uses computer data acquisition and process control technology with modern computer analysis to analyze servo motor systems.	6	1388
Optical Electronics (Bu-221, 224)	Instruction and research in electro-optics, fiber optics, and laser applications.	Excellent	Excellent – modern equipment and facilities.	8	2800
Underwater Acoustics (Sp-466, Ro-106)	Underwater transmission principles are taught, signal processing performed.	Fair	Adequate – more space is needed for instruction and research.	4	1000
Microwave (Sp-419, 419B, 419C, 604)	Provide instruction, computer simulation, design, and research of RF/microwave circuits, components, propagation, fields, and effects. Special emphasis on computational electromagnetic simulation techniques.	Fair	Good – High frequency principals and effects pertaining to circuit and system design are taught. Lab has Network Analyzer equipment covering 10 Hz–50 GHz; also a number of computers and workstations for EM simulation and design.	14	3862

TABLE XV (continued)
LABORATORY FACILITIES
Program __Naval Postgraduate School MSEE__

Facility (Bldg. & Rm. No.)	Purpose of Laboratory	Condition of Laboratory	Adequacy for Instruction	No. of Stations	Area (sq. ft.)
Special Signals (Sp-219)	Provides support for research and thesis students working on classified signals analysis.	Very good	Good for thesis support, but no space for instructional lab stations.	6	700
Computer Vision, Image Processing (Sp-301B, 546)	Research & instruction in contemporary computer vision techniques.	Very Good	Set up for thesis related research, equipment well-maintained.	8	1400
Academic Computing Lab (Sp-301A, 303, 431)	Provides general academic computer support to Department.	Excellent	Very Good – Constantly upgrading hardware and software to maintain competetive status.	24 SUN workstations, 19 486/50 or Pentiums	3100
Propagation Lab (Sp-537)	Thesis study & research on back scatter from ocean waves at low grazing angles.	Fair	Needs more space for equipment set up and for student study.	None	1080
Digital Signal Processing Lab (Sp-315)	Instruction & research in modern digital signal processing techniques.	Very Good	Very Good – needs more modern equipment. Getting SUN workstations.	8	800
Calibration and Repair Lab (Bu-112)	Provides repair & calibration of electronic test equipment used in classroom studies & research.	Fair	Lab needs more space & manpower. Overall lab is adequate.	None	1665
Image Processing (Sp-303B)	Provides hardware and software tools for study of digital image processing techniques.	Good	Adequate – hardware and software is being modernized with SUN workstations.	2	342
Power Lab (Bu 100A)	Provides for instruction and research in Power Systems for DoN and TSSE.	Excellent	Excellent – in the process of expanding floor space now.	2 PCs, 3 Sparcs	1800
Secure Computing Lab (Sp-548	Provides secure working space and computers for classified (up to DOD SECRET) word processing and calculations.	Excellent	Very good – 5 PCs, 3 Sparcs.	8	660

XIV. STUDENT DEVELOPMENT IN ENGINEERING PROFESSIONAL PRACTICE

A. Development of an understanding of the ethical, social, safety, and economic considerations in engineering practice

The officer-students at the Naval Postgraduate School are mature professionals who have demonstrated, during six or more years of experience in the military service, the necessary attributes to make professional success highly probable. As such, they are subject to and adhere to high standards of ethics and professionalism. The U.S. federal civilian students are also subject to rigid standards of conduct by virtue of their employment by the U.S. Government. Economic considerations in engineering practice are discussed in EC4010 (Defense Systems Engineering) and EC4000 (Future Engineering Practice). It is highly probable that every student will take at least one of these courses. In addition, the Superintendent's Guest Lecture Series frequently features speakers that address these subjects.

B. Opportunities on campus that are available to students for participation and membership in technical, professional and/or honor societies

IEEE -- A majority of the EC students belong to the student branch chapter of IEEE. The chapter encourages and assists students in becoming members of IEEE, sponsors informational programs, arranges tours of professional interest, promotes awareness of the IEEE and its publications, participates in regional activities, and serves as a focal point for student-faculty social contacts.

Eta Kappa Nu (HKN) -- NPS has an official chapter. Students are screened for admission on the basis of scholastic achievement. Selection is typically made after one year in residence.

IEEE and HKN working in conjunction organize semi-annual luncheons which enable new students to meet ECE faculty and become acquainted with research opportunities for thesis topics, engage in informal course and option area counselling, and maintain a hypertext database of all ECE faculty and their respective research interests in order to assist students in finding a thesis topic.

Sigma Xi -- Students who have demonstrated significant research potential are recommended for associate membership by thesis advisors. They are usually admitted near graduation.

Faculty members serve voluntarily as advisors in addition to their other duties. The Department assists by providing office space, areas for display of journals, contacts for speakers and field trips, and a modest amount of clerical assistance.

C. Ways interaction is enhanced between students and practitioners in industry, government, and private practice

The Department weekly seminar program provides student contacts with industrial and military personnel who are actively engaged in current engineering practices. In addition, NPS, in association with professional societies and DOD agencies, serves as host to numerous symposia and conferences to which students have access. Individual thesis investigations often involve interactions with industrial practitioners and/or DOD activities. Student field trips to industrial and/or Navy laboratories are regularly included in several courses. Quarter-length residence programs at a Navy Systems Command or a Navy Laboratory are also available to selected students.

D. Encouragement given to students to take the Fundamentals of Engineering examinations

Navy curricula sponsors have not supported the allocation of time for this purpose in ECE programs, preferring that emphasis be given to military applications. Nevertheless, informal assistance in taking both the EIT examination and the PE examination for the state of California are provided by the local student chapter of IEEE/HKN which assist students in preparing and registering for these examinations.

XV. INFORMATION REGARDING FACULTY MEMBERS

A. Faculty background

See Table XVI.

B. Course loads

See Table XVII.

C. Satisfaction of ABET engineering criteria for faculty size and applicable program criteria

The NPS ECE Department faculty size of 44 full-time dedicated faculty surpasses both the three FTE faculty required by the general criteria and the five experienced full-time members as required by the EE program criteria.

D. Curriculum vitae of faculty

Faculty vitae follow this section (starting on page II-369).

TABLE XVI
FACULTY ANALYSIS
Program Naval Postgraduate School MSEE

Name	Age	Rank	FT or PT	Highest Degree	Institution Where Highest Degree Earned & Year	Years of Experience: Govt/ Indust. Practice	Years of Experience: Total Faculty	Years of Experience: NPS	Professional Registration	Level of Activity in: Professional Society	Level of Activity in: Research	Level of Activity in: Consulting/ Summer Work in Industry
ADLER, Richard	60	Senior Lecturer	FT	PhD	Penn State, 1970	16	27	25	CA	High (ACES)	High	Med.
ASHTON, Robert	35	Assistant Professor	FT	PhD	Worcester, 1991	3	3	3	None	Low (IEEE, ASNE)	High	None
BERNSTEIN, Raymond	40	Visiting Instr.	FT	MSCS	NPS, 1982	12	5	5	None	Low (IEEE)	Med.	Med.
BORCHARDT, Randy	39	Visiting Instr.	FT	MSEE	NPS, 1988	14	3	3	None	Low (IEEE)	Med.	None
BUTLER, Jon	51	Professor	FT	PhD	Ohio State, 1973	3	21	11	Ohio	High (IEEE)	High	High
CIEZKI, John	29	Assistant Professor	FT	PhD	Purdue, 1993	0	1	1	None	Med. (IEEE)	High	Low
CRISTI, Roberto	43	Associate Professor	FT	PhD	Univ. Mass, 1983	4	12	10	None	Med. (IEEE, IFAC)	High	None
FARGUES, Monique	36	Associate Professor	FT	PhD	Virginia Tech, 1988	0	6	6	None	High (IEEE, SIAM)	High	None
FOUTS, Douglas	38	Assistant Professor	FT	PhD	UC Santa Barbara, 1990	3	5	5	None	Med. (IEEE, ACM)	High	None
GARCIA, Vicente	42	Visiting Associate	FT	MSEE	NPS, 1984	20	1	1	None	None	High	None
GILL, Gurnam	55	Visiting Associate	FT	PhD	S. Methodist U., 1971	15	5	5	None	Low (IEEE, AOC)	Med.	None
HA, Tri	46	Professor	FT	PhD	Univ. Maryland, 1977	6	12	8	None	Med. (IEEE)	High	None
HIPPENSTIEL, Ralph	53	Associate Professor	FT	PhD	NM State, 1985	8	13	9	None	Med. (IEEE)	High	None
HUTCHINS, R. Gary	45	Associate Professor	FT	PhD	UC San Diego, 1988	15	2	2	None	None	High	None
JANASWAMY, Rama	37	Associate Professor	FT	PhD	Univ. Mass, 1986	0	8	7	None	Med. (IEEE, AGU)	High	None

TABLE XVI (Continued)
FACULTY ANALYSIS
Program Naval Postgraduate School MSEE

						Years of Experience				Level of Activity in:		
Name	Age	Rank	FT or PT	Highest Degree	Institution Where Highest Degree Earned & Year	Govt/ Indust. Practice	Total Faculty	NPS	Professional Registration	Professional Society	Research	Consulting/ Summer Work in Industry
JENN, David	43	Associate Professor	FT	PhD	USC, 1987	14	5	5	None	High (IEEE, AIAA, ASEE)	High	Med.
KNORR, Jefferey	55	Professor	FT	PhD	Cornell, 1970	3	25	25	None	Low (IEEE)	Med.	None
LAM, Alex	37	Associate Professor	FT	PhD	Univ. Illinois, 1987	0	8	5	None	Med. (IEEE)	High	None
LEBARIC, Jovan	43	Visiting Associate	FT	PhD	Univ. Miss., 1987	2	7	2	None	Med. (IEEE, ACES)	High	High
LEE, Chin-Hwa	48	Professor	FT	PhD	UC Santa Barbara, 1975	0	20	17	None	Med. (IEEE)	High	None
LEE, Hung-Mou	46	Associate Professor	FT	PhD	Harvard, 1981	1	13	13	None	Med (AGU, AMS)	High	None
LEVIEN, Frederic	66	Senior Lecturer	FT	MSEE	Lehigh, 1967	34	5	5	None	High (IEEE, AOC	High	None
LOOMIS, Herschel	61	Professor	FT	PhD	MIT, 1963	2	32	14	CA	High (IEEE, ACM)	High	Med
LOTT, Gus	41	Assistant Professor	PT	PhD	NPS, 1990	9	2	1	VA and AL	None	High	None
MICHAEL, Sherif	44	Associate Professor	FT	PhD	U. of W. Virginia, 1983	0	12	12	WVA	High (IEEE, IIE)	High	None
MILLER, James	38	Associate Professor	FT	ScD	MIT, 1987	2	8	8	None	Med. (ASA, IEEE, AGU)	High	Low
MOOSE, Paul	57	Associate Professor	FT	PhD	Univ. Washington, 1970	15	18	15	None	Low (IEEE)	Med.	None
MORGAN, Michael	47	Professor	FT	PhD	UC Berkeley, 1976	4	18	16	None	Med. (IEEE, AGU)	High	None
PACE, Phillip	39	Associate Professor	FT	PhD	Ohio Univ., 1990	6	3	3	None	Med. (IEEE, AOC, SPIE)	High	None
PANHOLZER, Rudolf	67	Professor	FT	DrSc	U. Graz (Austria), 1961	2	37	30	None	Low (IEEE, ASEE)	Med.	Low

TABLE XVI (Continued)
FACULTY ANALYSIS
Program Naval Postgraduate School MSEE

Name	Age	Rank	FT or PT	Highest Degree	Institution Where Highest Degree Earned & Year	Years of Experience: Govt/ Indust. Practice	Years of Experience: Total Faculty	Years of Experience: NPS	Professional Registration	Level of Activity in: Professional Society	Level of Activity in: Research	Level of Activity in: Consulting/ Summer Work in Industry
PIEPER, Ron	44	Associate Professor	FT	PhD	U. of Iowa, 1984	1	11	5	VA	High (IEEE, OSA, SPIE)	High	None
POWERS, John	51	Professor	FT	PhD	UC Santa Barbara, 1970	0	25	25	None	Med. (IEEE, ASA, OSA SPIE)	Low	None
ROBERTSON, R. Clark	45	Associate Professor	FT	PhD	Univ. Texas, 1983	6	12	6	None	Med. (IEEE, AGU)	High	None
SCHLEHER, D. Curtis	63	Professor	FT	PhD	Polytechnic Univ., 1975	30	1	1	None	High (IEEE, AOC)	High	High
SHIELDS, Michael	36	Assistant Professor	FT	PhD	NPS, 1991	8	3	3	None	Low (IEEE)	Med.	Med
SHUKLA, Shridhar	33	Assistant Professor	FT	PhD	N. Carolina State, 1990	0	5	5	None	Med. (IEEE, ACM)	High	None
SMITH, Rasler	43	Visiting Instr.	FT	Elec. Eng.	NPS, 1990	11	1	1	None	None	High	None
TERMAN, Frederick	66	Senior Lecturer	FT	MSEE	Stanford, 1950	2	31	19	None	Low (IEEE, ACM)	None	None
THERRIEN, Charles	52	Professor	FT	PhD	MIT, 1969	12	11	11	None	Med. (IEEE)	High	None
TITUS, Harold	65	Professor	FT	PhD	Stanford, 1962	6	33	33	None	Low (IEEE)	Low	None
TUMMALA, Murali	37	Assistant Professor	FT	PhD	Indian Inst. Tech, 1984	6	9	9	None	Med. (IEEE)	High	None
WADSWORTH, Donald	64	Senior Lecturer	FT	PhD	MIT, 1958	31	7	7	CA	Low (IEEE, AOC)	Med.	Low
YUN, Xiaoping	33	Associate Professor	FT	PhD	Washington Univ., 1987	0	8	1	None	Med. (IEEE)	High	None
ZIOMEK, Lawrence	46	Professor	FT	PhD	Penn. State, 1981	2	13	13		Low (IEEE, ASA)	High	None

TABLE XVII
FACULTY ACTIVITY SUMMARY, PROGRAM Naval Postgraduate School MSEE

Faculty Member (Name)	FT or PT	Classes Taught (Course No./Credit Hrs.) Current Term	Total Activity Distribution					
			Teaching		Research		Other	
			Term	Year	Term	Year	Term	Year
ADLER, Richard	FT	EC2610 (3–1)	50%	16%	50%	84%	0%	0%
ASHTON, Robert	FT	EC3100 (3–2), TS3000 (3–2)	100%	52%	0%	48%	0%	0%
BERNSTEIN, Raymond	FT	Research Quarter	0%	38%	100%	62%	0%	0%
BORCHARDT, Randy	FT	EO2413(4–2)	50%	62%	50%	38%	0%	0%
BUTLER, Jon	FT	MA3030 (4–1), Crse Dev–Dist lng	100%	83%	0%	0%	0%	17%
CIEZKI, John	FT	EC4130 (4–2)	50%	58%	50%	42%	0%	0%
CRISTI, Roberto	FT	EO2402 (4–1), EC3400 (3–1)	100%	71%	0%	29%	0%	0%
FARGUES, Monique	FT	EC4470 (3–1), Course Dev.	50%	54%	0 %	46%	0%	0%
FOUTS, Douglas	FT	SS3035 (3–2), Crse Dev	100%	70%	0%	17%	0%	13%
GARCIA, Vicente	FT	EO3911 (3–0), EC3910 (3–0)	100%	63%	0%	27%	0%	0%
GILL, Gurnam	FT	EC2400 (3–1)	50%	38%	50%	62%	0%	0%
HA, Tri	FT	EC4550 (4–0), EC4580 (4–0)	100%	83%	0%	17%	0%	0%
HIPPENSTIEL, Ralph	FT	EC 1010 (1–1), EC4420 (3–1), MA1043 (2–0)	100%	71%	0%	29%	0%	0%
HUTCHINS, R. Gary	FT	EC3320 (3–2)	50%	69%	50%	31%	0%	0%
JANASWAMY, Rama	FT	EC2270 (4–2)	50%	70%	50%	13%	0%	17%
JENN, David	FT	EC4630 (3–0)	50%	30%	50%	70%	0%	0%
KNORR, Jefferey	FT	EC3610 (3-2)	50%	57%	50%	43%	0%	0%
LAM, Alex	FT	Intersessional	0%	33%	0%	25%	100%	42%
LEBARIC, Jovan	FT	EC3650 (4–1)	50%	21%	50%	13%	0%	66%
LEE, Chin-Hwa	FT	EC2820 (3–2), ED3830 (3–2)	100%	58%	0%	42%	0%	0%
LEE, Hung-Mou	FT	Leave	0%	63%	0%	12%	100%	25%
LEVIEN, Frederic	FT	EO4612 (4–2)	50%	13%	50%	13%	0%	74%

TABLE XVII (Continued)

FACULTY ACTIVITY SUMMARY, PROGRAM Naval Postgraduate School MSEE

Faculty Member (Name)	FT or PT	Classes Taught (Course No./Credit Hrs.) Current Term	Total Activity Distribution: Teaching Term	Teaching Year	Research Term	Research Year	Other Term	Other Year
LOOMIS, Herschel	FT	Admin	0%	38%	0%	38%	100%	24%
LOTT, Gus	PT	EC3500 (4–0)	50%	25%	0%	25%	50%	50%
MICHAEL, Sherif	FT	Intersession (Research)	0%	47%	100%	53%	0%	0%
MILLER, James	FT	Leave of Absence	0%	42%	0%	33%	100%	25%
MOOSE, Paul	FT	Intersession (Research)	0%	13%	100%	25%	0%	62%
MORGAN, Michael	FT	Research	0%	13%	100%	42%	0%	46%
PACE, Phillip	FT	EC3700 (3–3), Course Dev.	100%	75%	0%	25%	0%	0%
PANHOLZER, Rudolf	FT	EC2500 (3–2), Admin.	50%	38%	0%	24%	50%	38%
PIEPER, Ron	FT	EC3210 (3–1), EC4910 (3–1)	100%	63%	0%	37%	0%	0%
POWERS, John	FT	EC3550 (3–1), Dean of Engr & CS	50%	13%	0%	0%	100%	87%
ROBERTSON, R. Clark	FT	Intersessional (Research)	0%	40%	100%	60%	0%	0%
SCHLEHER, D. Curtis	FT	EC4980 (3–0), EO4011 (3–2)	100%	75%	0%	25%	0%	0%
SHIELDS, Michael	FT	EO2413 (4–2), EO3523 (4–2)	100%	63%	0%	37%	0%	0%
SHUKLA, Shridhar	FT	Leave of Absence	0%	27%	0%	44%	100%	29%
SMITH, Rasler	FT	EO3523 (4–2)	50%	25%	50%	75%	0%	0%
TERMAN, Frederick	FT	EC2220 (2–4), EC3800 (3–2), EC 4820 (3–1)	100%	75%	0%	0%	0%	25%
THERRIEN, Charles	FT	EC3410 (4–0), Course Dev.	100%	59%	0%	41%	0%	0%
TITUS, Harold	FT	EC2320 (3–0), EC4330 (2–2), EC 4340 (2–2)	100%	83%	0%	17%	0%	0%
TUMMALA, Murali	FT	EC3850 (3–0), Course Dev.	100%	60%	0%	40%	0%	0%
WADSWORTH, Donald	FT	EC2100 (4–2), EC2170 (4–2), CC4750 (3–1)	100%	66%	0%	34%	0%	0%
YUN, Xiaoping	FT	EC2300 (3-2), Research	50%	60%	50%	40%	0%	0%
ZIOMEK, Lawrence	FT	EC3450 (3–0), Research	50%	58%	50%	42%	0%	0%

1. Name and date of birth: **Richard W. Adler**, November 28, 1934

2. Academic rank: Senior Lecturer (full-time)

3. Degrees:

   Ph.D., Electrical Engineering, Pennsylvania State University, University Park, PA, December 1970
   M.S., Electrical Engineering, Pennsylvania State University, June 1958
   B.S., Electrical Engineering, Pennsylvania State University, June 1956

4. Number of years on faculty: 18

   Original Appointment: Assistant Professor, November 1969
   Associate Professor, September 1977
   Adjunct Research Professor, September 1985
   Senior Lecturer, September 1991

5. Related experience:

1978-1983	Senior Engineer, BDM Corporation, Assigned to support research at NPS EE Department.
1962-1969	Instructor (Full-time), Electrical Engineering Department, Pennsylvania State University.
1960-1961	Antenna Design Engineer, Hughes Aircraft Co.
1961-1962	Member Technical Staff, Aeronutronics, Inc.
1956-1958	Instructor (Half-time), Electrical Engineering Department, Pennsylvania State University.

6. Consulting: Lawrence Livermore National Laboratory (1975-present), Kershner & Wright (1983-present), Hatfield Dawson (1984-present), SRI International (1984), Pacific Sierra Research (1985), Delfin Systems (1989), Applied Researc Lab, Pennsylvania State University (1990-present).

7. Registered Professional Engineer, CA, (Electrical), 1983-present.

8. Principal Publications:

   Journal Papers

   Hunsucker, R. D., Adler, R. W., Lott, G. K., and Rose, R. B., "The Auroral-E Mode Oblique HF Propagation and its Dependence on the Auroral Oval," *IEEE APS Transactions* (accepted for publication in 1995).

   Breakall, J. K., Young, J. S., Hagn, G., Adler, R. W., Faust, D. L., and Werner, D. H., Modeling and Measurements of HF Antenna Skywave Radiation Patterns in Irregular Terrain, *IEEE APS Transactions*, Vol.42, No.7, pp. 936-945, July 1994.

   Breakall, J. K., Adler, R. W., and Elliniadis, P. D., An Investigation of Wird Grid and Surface Patch Modeling Using the Numerical Electromagnetics Code (NEC), *The Applied Computational Electromagnetics Society Journal*, Vol.9, No.2, pp. 93-113, 1994.

   Adler, R. W., "The History and Availability of NEC-MOM Codes for UNIX and PC Computers," *Applied Computational Electromagnetics Society Newsletter*, Vol. 8, No. 3, November 1993.

   Conference Proceedings/Abstracts/Presentations

   Adler, R. W., "Mitigation of Noise from Uninterruptable Power Supplies (UPS)," presented at Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1994.

   Adler, R. W., "Mitigation of Noise from a Small Telephone Switching System," presented at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1994.

   Adler, R. W., "EMI Software Recommendation for Use in SIGINT Receiving Site Encroachment Studies," presented at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1994.

   Adler, R. W., "Proposed Noise Current Injection Tests," presented at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1994.

   Hunsucker, R. D., Rose, R. B., Adler, R. W., and Lott, G. K., "First Results from the Alaska Auroral-E Propagation Experiment," workshop presentation and in *Proceedings of the Solar Terrestrial Prediction Workshop*, December 1993.

Adler, R. W., and Vincent, W. R., "Factors Affecting the Performance of Naval Receiving Sites," presentation and in *Proceedings of the NSA 2nd Annual EMC Conference*, April 1993.

Adler, R. W., "The Design of Portable Antennas for Use in Locating Sources of Power-Line Noise During SNEP Site Surveys," presented at the Workshop on Factors Affecting the Performance of Naval Receiving Sites, Naval Postgraduate School, February 1993.

Adler, R. W., "The Possibility of Using Active Antennas at Naval Receiving Sites," presented at the Workshop on Factors Affecting the Performance of Naval Receiving Sites," Naval Postgraduate School, February 1993.

Adler, R. W., Breakall, J. K., Pinion, D. J., and Resnick, A. F., "Low-Profile AM Antenna Design Study, Phase II -- Final Report," presented at the National Association of Broadcasters Radio '90 Conference, Boston, MA, September 15, 1990.

Adler, R. W., Breakall, J. K., Pinion, D. J., and Resnick, A. F., "Low-Profile AM Antenna Study, Phase II -- A Progress Report," presented at the National Association of Broadcasters Conference, Las Vegas, NV, April 1990.

Technical Reports

Vincent, W. R., and Adler, R. W., EMI Survey, Detachments J,K and L, Technical Report MSA9409 (SECRET), USA INSCOM MSAV, December 1994.

Vincent, W. R., and Adler, R. W., RFI/EMI Survey, Detachment L, Quick-Look Report, INSCOM Technical Report, September 1994.

Vincent, W. R., and Adler, R. W., RFI/EMI Survey, Detachment K, Quick-Look Report, INSCOM Technical Report, September 1994.

Vincent, W. R., and Adler, R. W., Performance Comparison of AN/FRD-10 vs. PUSHER, NPS Technical Report, EC-94-002, February 1994.

Vincent, W. R., and Adler, R. W., "Field Testing of Engineering Models of High-Dynamic Range Amplifiers," NSG Technical Report, December 1993.

Vincent, W. R., and Adler, R. W., "Receiving Conditions at NSGD Shemya," NSG Technical Report, August 1993.

Vincent, W. R., Adler, R. W., and Wadsworth, D. Z., "Quick-Look Report, USA Field Station KOREA and DMZ Det. L," INSCOM Technical Report, May 1993.

Vincent, W. R., Adler, R. W., and Wadsworth, D. Z., "Quick-Look Report, USA Field Station KOREA and DMZ Det. L," INSCOM Technical Report, May 1993.

9. Society member:

Institute of Electronic and Electrical Engineers: Antennas and Propagation, Engineering Education, Electromagnetic Compatibility, Broadcast Systems

Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and Sigma Tau

Executive Officer and Managing Editor of the Journal/Newsletter for the Applied Computational Electromagnetics Society, 1986-present.
Associate Editor of *Radio Science*.

10. Awards: Ford Foundation Predoctoral Fellowship (1962), NSF/NASA Summer Faculty Fellowship (1967), NEA/ASEE Summer Faculty Fellowship (1972).

11. Courses taught this year: None

12. Other duties: Full time research in Applied Electromagnetics, Signal-to-Noise Enhancement and HF Communications, and Antenna Numerical Modeling projects. Adviser for four MS student theses in 1994, three for 1995, and currently, one Ph.D. student.

13. Programs attended to improve professional competence: Coordinated and participated in teaching Computer Antenna Modeling Short Course each year for last three years.

14. Special duties of co-op faculty: Not applicable.

1. Name and date of birth: **Robert W. Ashton**, September 8, 1960

2. Academic rank: Assistant Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, Worcester Polytechnic Institute, May 1991
   M.S., Electrical Engineering, Worcester Polytechnic Institute, May 1989
   B.S., Electrical Engineering, Virginia Polytechnic Institute, December 1982

4. Number of years on faculty: 3

   Original appointment: Assistant Professor, July 1992

5. Related experience:

   1989-1991 Research Assistant, Worcester Polytechnic Institute, Worcester, MA. Extensive investigation unity power factor converters and electronicballasts for fluorescent lighting. Designed, prototype tested,and modeled a unique boost converter capable of both unity power factor operation and li conditioning. Developed and simulated an innovative method for controlling active power l conditioners using an adaptive estimation technique.

   1987-1989 Teaching Assistant, Worcester Polytechnic Institute, Worcester, MA. Instructed the followi courses: Power Electronics, Electromagnetics, Motors, Network Theory, Instrumentatic Transmission Lines, and Electrical Engineering Laboratory.

   1983-1986 Component Engineer, Unisys Corporation, Paoli, PA. TTL laboratory manager supervising f technicians. Design of special test fixtures for linear and digital integrated circuits to ver operational compliance to both military and corporate standards. Also developed software automated test equipment. Generated test procedures and requirement specifications for a vari of integrated circuits. Evaluation of test results.

   1989 (Summer) Electrical Engineer, Hercules Incorporated, Wilmington, DE. CAD system mechanical layout computer interface circuit card assembly.

   1987, 1989 (Summer) Design Engineer, Unisys Corporation, Paoli, PA. Designed and tested universal power control and feedback circuits for computer mainframes.

6. Consulting/patents: None

7. Not registered

8. Principal publications:

   Journal paper:

   Williams, S. M., and Ashton, R. W., "A New Approach for Teaching Electric Machinery: Object-Oriented Electric Machinery Simulation," *Computers in Education Journal*, 1995.

   Conference Proceedings/Abstracts/Presentations:

   Ashton, R. W., Emanuel, A. E., "An Adaptive Estimation Method for Harmonic Voltage Minimization by Means of Line Conditioners," IEEE Power Engineering Society Summer Meeting, San Diego, CA, July 1991.

9. Society member: IEEE, ASNE, Eta Kappa Nu

10. Honors and awards: ECE Department Outstanding Instructional Award for 1994, Northeast Utilities Fellowship 19 1991.

11. Courses taught (all courses are day courses):

Summer 95	EC4150, Advanced Solid State Power Conversion (4-1) (graduate course)
Winter 95	EC3150, Solid State Power Conversion (3-2) (graduate course)
Fall 95	EC2220, Applied Electronics (2-4) (undergraduate course) TS3000, Electrical Power Engineering (3-2) (this course is part of the Total Ship Systems Engineering program)
Summer 94	EC4150, Advanced Solid State Power Conversion (4-1) (graduate course) EC2110, Circuit Analysis II (3-2) (undergraduate course)

12. Other duties:

    Faculty Search Committee (1 hour per week)
    Department Head Search Committee (1/2 hour per week)
    Screening and Honors Committee (1 hours per week)
    Curriculum Committee (1 hour per week)
    TSSE Representative for ECE Department (1/2 hour per week)

13. Programs attended to improve professional competence: Advanced Instructional Workshop, 1994

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Raymond F. Bernstein, Jr.**, April 30, 1955

2. Academic rank: Visiting Instructor (full time)

3. Degrees:

   M.S., Computer Science, Naval Postgraduate School, Monterey, CA, 1982
   B.S., Mathematics, Texas Tech University, 1977

4. Number of years on faculty: 5

   Original appointment: Visiting Instructor, September 1989

5. Related experience:

   Naval service: Commissioned August 1977, resigned 1986.

   Duty stations:

   Two cruises on board USS Constellation
   Naval Intelligence Processing Systems Support Activity
   Office of Secretary of Defense (OSD)

   Corporate experience:

   Software AE: Project Manager, Software Engineer, and Software Consultant, 1986-1989

6. Consulting: Consulting experience in software engineering and digital signal processing.

7. Not registered

8. Principal publications:

   Conference Proceedings/Abstracts/Presentations

   Bernstein, R. F., Jr., and Loomis, H. H., Jr., "Cyclostationary Processing Using Butterfly Machines," presentation and in *Proceedings of the 1994 Conference on Information Science and Systems*, pp. 868-872, Princeton University, NJ, March 1994.

   Loomis, H. H., Jr., and Bernstein, R., Jr., "Realization of TDOA Estimation Architectures," poster paper presentation and in *Proceedings of the Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, pp. 1143-1151, November 1993.

   Loomis, H. H., Jr. and Bernstein, R., Jr., "Realization of TDOA Estimation Architectures," poster paper presented at the NSF Workshop of Cyclostationarity, W. A. Gardner, organizer, Yountville, CA, August 1992.

   Loomis, H. H., Jr., and Bernstein, R. F., Jr., "SSCA High Speed Parallel Architecture," presentation at the Spread Spectrum Workshop, Naval Postgraduate School, Monterey, CA, April 1992.

9. Society member: Sigma Xi, IEEE

10. Awards: None

11. Courses taught (all courses are day courses)

Spring 95	SS3035, Microprocessors and Space Applications (3-2) (graduate course)
Winter 95	EC2820, Introduction to Digital Systems (3-2) (undergraduate course)
Fall 95	EC2820, Introduction to Digital Systems (3-2) (undergraduate course)
Summer 94	EO3816, Computer Architectures for Military Applications (3-0) (graduate course)

12. Other duties: Thesis advising (4 hours per week)

   Research:

Spring 95	Half time research (20 hours per week)
Winter 95	Half time research (20 hours per week)

Fall 95	Half time research (20 hours per week)
Summer 94	Half time research (20 hours per week)

13. Programs attended to improve professional competence:

Attended two-day training course offered by the Naval Postgraduate School to improve teaching skills.

Currently pursuing a Ph.D. in Electrical and Computer Engineering at the Naval Postgraduate School.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Randy L. Borchardt**, July 7, 1956

2. Academic rank: Visiting Instructor (full time)

3. Degrees:

   Electrical Engineer, Naval Postgraduate School, June 1988
   M.S., Electrical Engineering (Space Systems Engineering), Naval Postgraduate School, Monterey, CA, June 19
   B.S., Mathematics, Rensselaer Polytechnic Institute, May 1978

4. Number of years on faculty: 2.5

   Original appointment: Visiting Instructor, September 1992

5. Related experience:

   Major, USA, variety of command and staff positions of increasing responsibility in aviation, research and development, acquisition, and military intelligence.

6. Consulting/patents: None

7. Not registered

8. Principal publications:

   Journal Paper

   Borchardt, R. L., and Ha, T. T., Capture Aloha with Two Random Power Levels, *Computer Communications*, Vol. 17, No. 1, pp. 67-71, January 1994.

   Conference Proceedings/Abstracts/Presentations

   Ha, T. T., Keiser, G. E., and Borchardt, R. L., "Analysis of Direct Detection Lightwave Systems with Optical Amplifiers," presentation and in *MILCOM 94 Conference Records*, Fort Monmouth, NJ, pp. 357-361, October 2-5, 1994.

   Technical Reports

   Borchardt, R. L., Ha, T. T., and Robertson, R. C., "Development of Protocols for Maritime Mobile Communication," NPS Technical Report EC-93-021, November 1993.

   Lundholm, S. E., Robertson, R. C., and Borchardt, R. L., "Predicting Antenna Parameters from Antenna Physical Dimensions," NPS Technical Report EC-93-019, December 1993.

9. Society member: IEEE, Eta Kappa Nu

10. Awards: Space Systems Engineering Award, Naval Postgraduate School, 1989

11. Courses taught (all courses are day courses):

Winter 95	EC2010, Probabilistic Analysis of Signals and Systems (3-1) (undergraduate course)
Summer 95	EC2010, Probabilistic Analysis of Signals and Systems (3-1) (undergraduate course)
	EO3513, Communications Systems Analysis (4-2) (2 sections) (graduate course)

12. Other duties:

   Fall/Spring 95 Research in Communications and High-Speed Analog-to-Digital Conversion Techniques

13. Programs attended to improve professional competence: In pursuit of a Ph.D. in electrical engineering.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Jon T. Butler**, December 26, 1943

2. Academic rank: Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, The Ohio State University Columbus, OH, March 1973
   M.Engrg., Electrical Engineering, Rensselaer Polytechnic Institute, Troy, NY, August 1967
   B.E.E., Electrical Engineering, Rensselaer Polytechnic Institute Troy, NY, June 1966

4. Number of years on faculty: 8

   Original appointment: Professor, September 1987

5. Related experience:

1974-1987	Associate Professor, Dept. of Electrical Engineering and Computer Science, Evanston, IL (Ass Prof., 1974-79) On leave 1980-1981 and 1985-1987 at the Naval Postgraduate School
1980-1981	Senior Postdoctoral Associate of the National Research, Naval Postgraduate School

6. Patents/consulting: None

7. Registered in Ohio

8. Principal publications:

Book

Butler, J. T., *Multiple-Valued Logic in VLSI*, IEEE Computer Society Press, June 1991.

Journal Papers

Butler, J. T., "Multiple-Valued Logic in Ultra-High Speed Computation," *IEEE Potentials*, pp. 11-14, April/May 1995.

Butler, J. T., "Research on Multiple-Valued Logic at the Naval Postgraduate School," *Naval Research Reviews*, Vol. XLIV/XLV, Four/1992 One/1993, pp. 1-8 (not refereed).

Dueck, G. W., and Butler, J. T., "A Minimization Algorithm for Nonconcurrent PLAs," *International Journal of Electronics*, Vol. 73, No. 6, pp. 1113-119, December 1992.

Schueller, K. A., and Butler, J. T., "On the Design of Cost-Tables for Realizing Multiple-Valued Circuits," *IEEE Transactions on Computers*, pp. 178-189, February 1992.

Tirumalai, P. P., and Butler, J. T., "Minimization Algorithms for Multiple-Valued Programmable Logic Arrays," *IEEE Transactions on Computers*, pp. 167-177, February 1991.

Butler, J. T., "On the Number of Propagation Paths in Multilayer Media," *Fibonacci Quarterly*, Vol. 28, No. 4, pp. 334-339, November 1990.

Butler, J. T., and Schueller, K. A., "On the Equivalence of Cost Functions in the Design of Circuits by Costables," *IEEE Transactions on Computers*, Vol. C-39, pp. 842-844, June 1990.

Lee, J. K., and Butler, J. T., "A Characterization of t/s-Diagnosability and Sequential t-Diagnosability in Designs," *IEEE Transactions on Computers*, Vol. C-39, pp. 1298-1304, October 1990.

Conference Proceedings/Abstracts/Presentations

Sasao, T., and Butler, J. T., "Planar Multiple-Valued Decision Diagrams," presentation and in the *Proceedings of the 25th International Symposium on Multiple-Valued Logic*, pp. 28-35, May 1995.

Butler, J. T., and Sasao, T., "Multiple-Valued Combinational Circuits with Feedback," presentation and in *Proceedings of the 24th International Symposium on Multiple-Valued Logic*, pp. 342-347, May 1994.

Sasao, T., and J. T. Butler, "A Decision Method for Look-Up Table Type FPGA by Pseudo-Kronecker Expansion," *Proc. of the 24th International Symposium on Multiple-Valued Logic*, pp. 97-106, May 1994.

Dueck, G., and Butler, J. T., "Multiple-Valued Operations with Universal Literals," *Proceedings of the 24th International Symposium on Multiple-Valued Logic*, pp. 73-79, May 1994.

C. Yildirim, J. T. Butler, and C. Yang, "Multi-valued PLA Minimization by Concurrent Multiple and Mixed Simulated Annealing," presentation and in *Proceedings of the 23rd International Symposium on Multiple-Valued Logic*, pp. 17-23, May 1993.

Sasao, T., and Butler, J. T., "On the Analysis of an FPGA Architecture," presentation and in *Proceedings of the International Symp. on Logic Synthesis and Microprocessor Architecture*, pp. 162--168, July 1992.

Butler, S. W., and Butler, J. T., "Profiles of Topics and Authors of the International Symposium on Multiple-Valued Logic," presentation and in *Proceedings of the International Symposium on Multiple-Valued Logic*, pp. 372--379, May 1992.

Dueck, G. W., Earle, R. C., Tirumalai, P. P., and Butler, J. T., "Multiple-valued Programmable Logic Array Minimization by Simulated Annealing," presentation and in *Proceedings of the International Symposium on Multiple-Valued Logic*, pp. 66--74, May 1992.

Butler, J. T., and Schueller, K. A., "Worst Case Number of Terms in Symmetric Multiple-Valued Functions," presentation and in *Proc. of 21st Intl Symp. on Multiple-Valued Logic*, pp. 94-101, May 1991.

Chang, Y.-H., and Butler, J. T., "The Design of Current-Mode CMOS Multiple-Valued Circuits," presentation and in *Proc. of the 21st International Symposium on Multiple-Logic*, pp. 130-138, May 1991.

Butler, J. T., Kerkhoff, H. G., and Onneweer, S., "A Comparative Analysis of Multiplexer Techniques for the Minimization of Function Cost Using the Costable Approach," presentation and in the *Proceedings of the 20th International Symposium on Multiple-Valued Logic*, pp. 286-291, May 1990.

Schueller, K. A., Butler, J. T., "The Costtable Problem is NP-Complete," in the *Proceedings of the 28th Annual Allerton Conf. on Communication, Control, and Computing*, October 1990, regular (full) paper.

Yurchak, J., and Butler, J. T., "HAMLET - An Expression Compiler/Optimizer for the Implementation of Heuristics to Minimize Multiple-Valued Programmable Logic Arrays," presentation and in the *Proceedings of the 20th International Symposium on Multiple-Valued Logic*, pp. 144-152, May 1990.

9. Society member:

Fellow of Institute of Electrical and Electronics Engineering
Member of Sigma Xi, Eta Kappa Nu, and Tau Beta Pi
Member, Board of Governors of the IEEE Computer Society, 1991 to present
Chairman of Computer Society's Magazine Advisory Committee, 1990-1991 (member 1989 to present)
Vice Chair for Hardware, Computer Society Technical Activities Board, 1986-1988; First Vice Chair, 1987-1988
Distinguished Visitor of the IEEE Computer Society, 1982-1985
Chairman, Multiple-Valued Logic Technical Committee of the IEEE Computer Society, 1980-1982

10. Awards:

Meritorious Service Award, IEEE Computer Society, 1992 and 1988
Certificate of Appreciation, IEEE Computer Society, 1991, 1989, and 1982
Outstanding Contributed Paper Award, 16th International Symposium on Multiple-Valued Logic, Blacksburg, VA, 19
Award for Excellence, The Multiple-Valued Logic Technical Committee, for a paper contributed to the 15th Internatior
Symposium on Multiple-Valued Logic, Kingston, Ontario, Canada, 1985
Faculty Honor Roll, Top 5% as determined by the Association for Student Government of Northwestern Univ., 19
NAVALEX Chair Professor, Naval Postgraduate School, 1985-87
Who's Who Listing: Who's Who in America (1992-1995), American Men and Women in Science (1992), Who's W
in Engineering (1985), Outstanding Young Men in America (1980), Who's Who in Technology Today (1980)

11. Courses taught (all are day courses):

Spring 95	EC2820, Digital Logic Design (3-2) (undergraduate course)
	EC3800, Microprocessor Based System Design (3-2) (graduate course)
Winter 95	EC2800, Introduction to Microprocessors (3-2) (undergraduate course)
Fall 94	EC3800, Microprocessor Based System Design, 2 sections (3-2) (graduate course)

12. Other duties:

Editor-in-Chief, *Computer Society Press -- Advances*, 1993 to present, Editor, 1986-1990.
Editor-in-Chief, *Computer*, 1991 to 1992, Associate Technical Editor, 1990-1991, Editor, 1989-1990.
Editor, *IEEE Transactions on Computers*, 1982-1986.

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **John G. Ciezki**, September 23, 1966

2. Academic rank: Assistant Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, Purdue University, 1993
   M.S., Electrical Engineering, Purdue University, 1990
   B.S., Electrical Engineering, Purdue University, 1988

4. Number of years on faculty: 1

   Original appointment: March 1994

5. Related Experience:

   1993-1994 Post-Doctoral Research Position, Purdue University
   1989-1993 Research Assistant, Purdue University
   1989-1991 Teaching Assistant, Purdue University
   1989-1990 Undergraduate Academic Counselor, Purdue University

6. Consulting: P. C. Krause & Associates, projects sponsored by Naval Surface Warfare Center and NASA, 1991-pres

7. Not registered

8. Principal publications:

   Journal Papers

   Ashton, R., and Ciezki, J. G., "A Navy-Oriented Power System Program," *IEEE Transactions on Power Systems*, submitted May 1995.

   Ciezki, J. G., "Average Value Analysis of a Parallel Output Resonant Converter, to be submitted to *IEEE Transactions on Aerospace and Electronic Systems.*

   Ciezki, J. G., and Ashton, R., "A Comparison of Methods of Solving Stiffly-Connected, Finite-Inertia Power System Simulation Problems," to be submitted to *IEEE Transactions on Energy Conversion.*

   Technical Reports

   P. C. Krause and Associates, "IPS Component/System Model Development," Interim Technical Report, Contract No. 0002494-C-4180 for Naval Sea Systems Command, December 1993.

   Ciezki, J. G., Gareis, G. E., Krause, P. C., Sudhoff, S. D., and Wasynczuk, O., "Computer Models of Shipboard Electrical Power Systems," Final Report, Contract No. N61533-89-D-0037C for Naval Surface Warfare Center, October 1993.

   Ciezki, J. G., Krause, P. C., Sudhoff, S. D., and Wasynczuk, O., "Investigation of Advanced Power Sources and Actuator Systems for Future Aerospace Vehicles," Final Technical Report, Contract No. NAS3-25962 for NASA Lewis Research Center, April 1993.

   Branson, M., Ciezki, J. G., Sudhoff, S. D., and Wasynczuk, O., "Electric Drive Modeling and Performance Studies," Interim Technical Report, Contract No. N61533-89-D-0037 for David Taylor Research Center, June 1991.

   Other

   Ciezki, J. G., "The Analysis and Reduced-Order Modeling of a Proposed Aerospace Electric Drive," Ph.D. Dissertation, Purdue University, 1993.

   Ciezki, J. G., "The Analysis and Control of Parametric Instability in Permanent Magnet Stepper Motors," M.S. Thesis, Purdue University, 1990.

9. Society member: IEEE, Tau Beta Pi, HKN

10. Awards: None

11. Courses taught (all courses are day courses):

    Spring 95 EC3130, Electrical Machinery Theory (4-2) (graduate course)

	EO2402, Introduction to Linear Systems (4-1) (undergraduate course)
Fall 95	EC4130, Advanced Electrical Machinery Systems (4-2) (graduate course)
Summer 94	EC3130, Electrical Machinery Theory, (4-2) (graduate course)

12. Other duties:

Winter 95	Research and course development (full time)
Fall 95	Research and course development (half time)
Summer 94	Research and course development (half time)
Spring 94	Research and course development (half time)

Thesis Advising: 4 hours per week

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Roberto Cristi**, September 3, 1952

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical and Computer Engineering, University of Massachusetts, Amherst, MA, September 1983
   M.Sc., Electrical Engineering, UMIST and Brunel University, Uxbridge, Middx, GB, March 1978
   "Laurea", Electrical Engineering, Universita' di Padova, Padua, Italy, March 1977

4. Numbers of years on faculty: 10

   Original appointment: Assistant Professor, September 1985
   Promotion: Associate Professor, July 1988

5. Related experience:

1983-1985	Visiting Assistant Professor, Electrical Engineering Department, University of Michigan
1983	Postdoctoral Research in Digital Image Segmentation, Electrical and Computer Engineeri Department, University of Massachusetts
1980-1982	Research Assistant under Prof. R. Monopoli, Electrical and Computer Engineering, University Massachusetts
1979	Engineer, Power Automation and Telemetry Department, Fisher Controls Ltd, Leicester, UK
1977	Teaching Assistant, "Istituto di Elettrotecnica", University of Padua, Italy

6. Consulting/patents: Consultant for the Advanced Transmission Engineering of Ford Motor Company, Livonia, I (1985).

7. Not Registered

8. Principal publications:

Journal Papers

Cristi, R., Burl, J., and Russo, N., "Adaptive Quaternion Feedback Regulation for Eigenaxis Rotations," *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 17, No. 6, November-December 1994.

Feuer, A., and Cristi, R., "On the Optimal Weight Vector of a Perceptron," *IEEE Transactions on Signal Processing*, June 1993.

Feuer, A., and Cristi, R., "On the Steady State Performance of Frequency Domain LMS Algorithms," *IEEE Transactions on Signal Processing*, January 1993.

Healey, A., McGhee, R., Cristi, R., Papoulias, F., Kwak, S., Kanayama, Y., Lee, Y., Shukla, S., and Zaky, A., "Research on Autonomous Underwater Vehicles at the Naval Postgraduate School," *Naval Research Reviews*, Vol. XLIV, No. 1, 1992.

Cristi, R., "Markov and Recursive Least Squares Methods for the Estimation of Data with Discontinuities," *IEEE Transactions on Acoustics, Speech and Signal Processing*, November 1990.

Cristi, R., and Feuer, A., "On the Persistency of Excitation for Systems Having Purely Deterministic Disturbances," *International Journal on Adaptive Control and Signal Processing*, Vol. 4, No. 5, September-October 1990.

Cristi, R., Papoulias, F. A., and Healey, A. J., "Adaptive Sliding Mode Control of Autonomous Underwater Vehicles in the Dive Plane," *IEEE Journal of Oceanic Engineering*, July 1990.

Das, M., Cristi, R., "Robustness of an Adaptive Pole Placement Algorithm in Presence of Bounded Disturbances and Slow Time Variations of the Parameters," *IEEE Transactions on Automatic Control*, August 1990.

Conference Proceedings/Abstracts/Presentations

Therrien, C. W., Cristi, R., and Allison, D. E., "Methods for Acoustic Data Synthesis," IEEE DSP Workshop, Yosemite National Park, California, October 1994.

Cristi, R., "Navigation and Localization in a Partially Known Environment," *Proceedings of AUV 94*, Cambridge, MA, July 19-20, 1994.

Cristi, R., "Sensor Based Navigation of an Autonomous Underwater Vehicle," presentation and in *Proceedings of the 9th International Symposium on Unmanned, Untethered Submersible Technology*, NH, September 1993.

Cristi, R., and Burl, J., "Adaptive Eigenaxis Rotation," presentation and in *Proceedings of the European Control Conference*, Delft, The Netherlands, June 1993.

Fargues, M. P., Cristi, R., and Vanderkamp, M. M., "Modeling and Classification of Biological Signals Using the Least-Squares Prony-SVD AR Modeling," presentation and in *Proceedings of the 36th Symposium on Circuits and Systems*, Detroit, MI, August 1993.

Jamali, J., Wood, S. L., and Cristi, R., "Experimental Validation of the Kroneker Product Godard Blind Adaptive Algorithm," presentation, 26th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, November 1992.

Michael, S., and Cristi, R., "Active Compensated Integrated Programmable Operational Amplifiers with Improved Characteristics," presented at the 1991 International Symposium on Circuits & Systems (IASTED), Zurich, Switzerland, pp. 73-76, July 1991.

Cristi, R., Healey, R. J., and Papoulias, F. A., "Dynamic Output Feedback by Robust Observer and Variable Structure Control," presentation and in the *Proceedings of the 1990 American Control Conference*, San Diego, CA, May 1990.

Cristi, R., Michael, S., "An Estimation Theoretic Approach to the Detection of PSK Signals," presentation and in the *Proceedings of the IEEE Symposium on Circuits and Systems*, New Orleans, LA, pp. 1788-1792, April 1990.

Michael, S., Cristi, R., "Integrated Programmable Operational Amplifiers With Improved Characteristics," presentation and in the *Proceedings of the 1990 European Conference on Applied Specific Integrated Circuits (EURO ASIC)*, Paris, France, pp. 74-79, May 1990.

9. Society member: IEEE, International Federation of Automatic Control (IFAC), Tau Beta Pi, Sigma Xi

10. Award: Research Assistantship at the University Massachusetts, Amherst, 1980-1982

11. Courses taught (all are day courses):

Spring 95	EC2410, Analysis of Signals and Systems (3-1) (undergraduate course)
	EC3400, Digital Signal Processing (3-1) (graduate course)
Winter 95	EC2410, Analysis of Signals and Systems (3-1) (undergraduate course0
Spring 94	EC3410, Discrete Time Random Processes (4-0) (graduate course)
	EC4360, System Identification (3-1) (graduate course)
Fall 93	EC4420, Modern Spectral Estimation (3-1) (graduate course)
	EC2400, Discrete Systems (3-2) (undergraduate course)
Summer 93	EC4350, Nonlinear Control Systems (3-1) (graduate course)
Spring 93	EC4360, System Identification (3-1) (graduate course)
Fall 92	EC2400, Discrete Systems, 2 sections (3-2) (undergraduate course)

12. Other duties:

Research

1995-1996	Sensor Based Navigation for Autonomous Underwater Vehicles sponsored by the Office of Nava Research
1994-1995	Sensor Based Navigation for Autonomous Underwater Vehicles sponsored by the Office of Nava Research
1993, 1994	Automatic Control of an Extremely High Frequency (EHF) Antenna, sponsored by NISE Wes Vallejo, CA

13. Programs attended to improve professional competence: Short Course on Analog Mos Integrated Circuits taught UCLA in October 1986.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Monique P. Fargues**, July 10, 1959

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, Virginia Polytechnic Institute and State University (VPI&SU), August 1988
   M.S., Electrical Engineering, Virginia Polytechnic Institute and State University, October 1984
   Engineering Diploma, Ecole Superieure d'Ingenieurs en Electronique et Electrotechnique, Paris, France, June 19

4. Number of years on faculty: 6

   Original appointment: Assistant Professor, January 1989
   Promotion: Associate Professor, July 1995
   Award of Academic Tenure: July 1995

5. Related experience:

Sep. 1985-July 1987	Graduate Research Assistant, Department of Electrical Engineering, VPI&SU. Proje Title: Non-Linear Spectral Estimation for Array Processing. Research sponsored UNISYS (SPERRY) Corporation and the Center for Innovative Technology.
Jan.-July 1985	Graduate Research Assistant, Department of Electrical Engineering, VPI&SU. Proje Title: Design and Implementation of a Short Term Load Forecasting System. Researc partially sponsored by Old Dominion Electric Cooperative.
Jan.-July 1983	Graduate Research Assistant, Department of Electrical Engineering, VPI&SU. Proje Title: Analytical Techniques for Switched-Capacitor Filters Research sponsored by IB Federal Systems Division.
Sep. 1987-Mar. 1983	Graduate Assistant, Department of Electrical Engineering, VPI&SU.
Sep. 1983-Dec. 1984	Graduate Assistant, Department of Electrical Engineering, VPI&SU.

6. Patents/consulting: None

7. Not Registered

8. Principal publications:

Journal Papers

Beex, A. A., Wilkes, M., and Fargues, M. P., "Toeplitz-Derived Hermitian Eigendecomposition," accepted for publication in *IEE Proceedings-Series F, Radar & Signals Processing*, February 1995.

Fargues, M. P., and Ferreira, M. P., Investigations in the Numerical Behavior of the Adaptive Rank-Revealing QR Factorization, accepted for publication, *IEEE Transactions on Signal Processing*, Feb. 1995.

Fargues, M. P., and Brooks, W. A., "A Comparative Study of Time-Frequency and Time-Scale Transforms for Ultra-Wideband Radar Transient Signal Detection," accepted for publication, subject to minor revisions, in *IEE Proceedings-Series F, Radar & Signal Processing*, January 1995.

Beex, A. A., and Fargues, M. P., "Analysis of Clock Jitter in Switched-Capacitor Systems," *Trans. Circuits and Systems, Part 1: Fundamental Theory and Applications*, Vol. 39, No. 7, pp. 506--519, July 1991.

Fargues, M. P., and Beex, A. A., "Fast Order-Recursive Generalized Hermitian Toeplitz Eigenspace Decomposition," *Mathematics of Control, Signals, and Systems*, Vol. 3, No. 4, pp. 65-95, 1990.

Conference Proceedings/Abstracts/Presentations

Fargues, M. P., and Brown, W. D., "Introduction to Signal Processing using the SPC Toolbox," Invited Paper, presentation and in *Proceedings of the 28th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, November 1994.

Fargues, M. P., Coutu, G., Stearns, S. D., and Plaza, D., "Adaptive Systems with Coefficients Indicating Frequency," *Proceedings of the 28th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, November 1994.

Fargues, M. P., and Brown, D. W., "Teaching Signal Processing Concepts Using the SPC Toolbox," *Proceedings of the 6th Digital Signal Processing Workshop*, Yosemite Lodge, CA, Oct. 2-5, 1994.

Fargues, M. P., Coutu, G., and Stearns, S. D., "Seismic Waveform Compression using Adaptive Filters," *Proceedings of the 37th Midwest Symposium on Circuits and Systems*, Lafayette, LA, August 3-5, 1994.

Fargues, M. P., and Hippenstiel, R., "Robust Spectral-Based Techniques for Classification of Wideband Transient Signals," presentation and in *Proceedings of the 7th Signal Processing Workshop on Statistical Signal and Array Processing*, pp. 379-382, Quebec City, Canada, June 26-29, 1994.

Four additional conference papers published during 1991-1993.

Technical Reports (Three additional reports prepared during 1993-1990)

Hippenstiel, R., and Fargues, M., Feature Extraction from Digital Communication Signals Using Wavelet Transforms, NPS Technical Report EC-95-001, February 8, 1995.

Fargues, M., TLS-Based Prefiltering Technique for Time-Domain ARMA Modeling, NPS Technical Report EC-94-009, ONR, Code 1114, Arlington, Virginia, August 1994.

Dewey, J. K., Fargues, M., and Hippenstiel, R., Electrostatic Target Detection: A Preliminary Investigation, NPS Technical Report EC-94-001,, U. S. Army Laboratory, Adelphi, Maryland, January 1994.

9. Society member: IEEE Senior Member; IEEE Acoustic, Speech, and Signal Processing Society; SIAM, SPIE, Eta Kappa Nu, Sigma Xi, AAUW

10. Award: Akzona Fellowship, Department of Electrical Engineering, VPI&SU, Blacksburg, VA, 1988.

11. Courses taught (all courses are day courses):

Winter 95	EC3420, Statistical Digital Signal Processing (3-1) (graduate course)
Fall 95	EO2413-2, Introduction to Communications Systems Engineering (4-2) (undergraduate course)
	EC4470, Adaptive Signal Processing (3-1) (graduate course)
	EC4900, Special Topics in Electrical Engineering, Introduction to Speech Processing (3-0) (graduate course)
Spring 94	EC4410, Speech Signal Processing (3-1) (graduate course)
	EC4900, Special Topics in Electrical Engineering, Lossless Data Compression (3-0) (graduate course)

12. Other duties:

Associate editor, *IEEE-SP Transactions*.
Member, Review panel for fiscal year 94 In-House Laboratory Independent Research Program at NAWC, Aircraft Division, Warminster, PA, September 1994.
Member, Steering Committee for the Asilomar Conference on Signals, Systems, and Computers.
Reviewer: *IEEE-SP Transactions* and *IEE Proceedings*

Research:

Winter 95	Half time research, DFR funding, sponsored by NCCOSC (20 hours per week)
Summer 95	Full time research, sponsored by Space and Naval Warfare Systems Command (40 hours per week)
Spring 94	Half time research, DFR funding, sponsored by ONR (20 hours per week)
Winter 94	Half time research, DRF funding, sponsored by ONR (20 hours per week)

13. Programs attended to improve professional competence:

24th-28th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, 1990-1994.
6th Digital Signal Processing Workshop, Yosemite National Park, CA, October 1994.
7th IEEE-SSAP Workshop on Statistical and Array Processing, Quebec City, Canada, June 1994.
Three-hours tutorial, "Numerical Methods in Signal and Image Processing," given by R. J. Plemmons (from Wake Forest University), Seattle, WA, August 1993.
4th SPIE Conf. on Advanced Signal Processing Algorithms, Architecture, and Implementation, San Diego, CA, 1993.
1993 IEEE International Conference on Acoustics, Speech, and Signal Processing, Minneapolis, MN, April 1993.
Three-hour tutorial, "Introduction to Wavelet Based Signal Analysis," given by C. S. Burruss (from Rice University), Minneapolis, MN, April 1993.
Three-hour tutorial, "Digital Neural Networks," given by S.-Y. Kung (from Princeton University), Minneapolis, MN, April 1993.
IEEE-SP International Symposium on Time Frequency and Time-Scale Analysis, Victoria, B.C., Canada, October 1992.
6th IEEE-SSAP Workshop on Statistical and Array Processing, Victoria, B.C., Canada, October 1992.
1992 IEEE International Conference on Acoustics, Speech, and Signal Processing, San Francisco, CA, March 1992.
1991 IEEE International Conference on Acoustics, Speech, and Signal Processing, Toronto, Canada, May 1991.
Symposium on Applications of Wavelets to Signal Processing, sponsored by the Air Force Institute of Technology (AFIT) and Air Force Office of Scientific Research (AFSOR), Wright-Patterson Air Force Base, OH, March 1991.
1990 IEEE International Conference on Acoustics, Speech, and Signal Processing, Albuquerque, NM, April 1990.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Douglas Jai Fouts**, March 19, 1957

2. Academic rank: Assistant Professor (full time)

3. Degrees:

   Ph.D., Electrical and Computer Engineering, University of California, Santa Barbara, CA, July 1990
   M.S., Electrical and Computer Engineering, University of California, Santa Barbara, CA, December 1984
   B.A., Computer Science, University of California, Berkeley, CA, August 1980

4. Number of years on faculty: 5

   Original appointment: Assistant Professor, September 1990

5. Related experience:

1985-1990	Research Assistant, Department of Electrical and Computer Engineering, University of Califor Santa Barbara, CA.
1980-1983	Associate Engineer, Burroughs Corporation (now UNISYS), Computer Systems Group, Miss Viejo, CA.
1986 (Sep-Dec)	Visiting Lecturer, Department of Electrical and Computer Engineering, University of Califor Santa Barbara, CA.
1985 (Aug)	Instructor, University of California Extension Service, Santa Barbara, CA.
1979 (Jun-Sep)	Student Engineer, The Aerospace Corporation, Space Computers Laboratory, El Segundo, C

6. Consulting: Digital Equipment Corporation, Tasker/Whitiker Engineering.

7. Not registered

8. Principal publications:

   Journal Papers

   Fouts, D. J., Weatherford, T., McMorrow, D., Melinger, J. S., and Campbell, A. B., "Single Event Upsets in Gallium Arsenide Dynamic Logic, "*IEEE Transactions on Nuclear Science*, Vol. 41, No. 6, pp. 2244-2251, December 1994.

   Fouts, D. J., and Billingsley, A. B., "Predictive Read Caches: An Alternative to On-Chip Second-Level Cache Memories," *Journal of Microelectronic Systems Integration*, Vol. 2, No. 2, No. 2, pp. 109-121, June 1994.

   Fouts, D. J., "A Gallium Arsenide Digital Phase Shifter for Clock and Control Signal Distribution in High-Speed Digital Systems," *IEEE Journal of Solid State Circuits*, Vol. 27, No. 5, pp. 802--809, May 1992.

   Fouts, D. J. and Butner, S. E., "Architecture and Design of a 500 MHz Gallium Arsenide Processing Element for a Parallel Super Computer," *IEEE Journal of Solid State Circuits, Second Special Issue on Microelectronic Systems*, Vol. 26, No. 9, pp. 1199-1211, September 1991.

   Conference Proceedings/Abstracts/Presentations

   Fouts, D. J., Weatherford, T. R., McMorrow, D., Wolfe, K., Van Dyk, S. E., and Campbell, A. B., "Single Event Upsets in Gallium Arsenide Pseudo-Complementary MESFET Logic," 32nd Annual International Nuclear and Space Radiation Effects Conference, Madison, WI, July 1995.

   Fouts, D. J., Weatherford, T., McMorrow, D., Melinger, J. S., and Campbell, A. B., "Single Event Upsets in Gallium Arsenide Dynamic Logic," 31st Annual International Nuclear and Space Radiation Effects Conference, Tucson, AZ, July 1994.

   Richstein, J. K., Fouts, D. J., Pieper, R. J., Poon, T. C., "A CMOS VLSI IC For Real-Time Opto-Electronic Two-Dimensional Histogram Generation," *Proceedings of the 26th IEEE Southeastern Symposium on System Theory*, Athens, Ohio, pp. 390-394, March 1994.

   Richstein, J. K., Fouts, D. J., Pieper, R. J., and Poon, T.-C., "A CMOS VLSI IC for Real-Time Opto-Electronic Two-Dimensional Histogram Generation," presented at the 26th IEEE Southeastern Symposium on System Theory, Ohio University, Athens, OH, March 20-22 1994.

   Fouts, D. J., "Testing High-speed Digital Integrated Circuits", presentation at the Workshop on Testing High-Speed Integrated Circuits, University of California at Santa Barbara, October 1992.

Fouts, D. J., and Gonter, T. C., "A Microprocessor Interface for Ferroelectric Capacitor Memory," presentation, 26th Annual Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, October 1992.

Billingsly, A., Fouts, D. J., and Hamming, R., "Memory Latency Reduction Using an Address Prediction Buffer," presentation, 26th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, October 1992.

Fouts, D. J., "Gallium Arsenide Digital Integrated Circuits: Current Technology, Future Trends and Influences on Computer Architectures," presented at the Young Ph.D. Seminar Series, Boston, MA, September 1991.

Fouts, D. J., "A Phasing Adjustment and Fanout Buffer for Distributing Clock and Control Signals in High-Speed Digital Systems," presented at the IEEE Midwest Symposium of Circuits Systems, Monterey, CA, May 1991.

Fouts, D. J., "A History of Early Computers and Calculating Machines," guest lecture presented before the Naval Postgraduate School Military Affiliate Radio Service and Amateur Radio Club, Monterey, CA, February 1991.

9. Society member: IEEE, IEEE Computer Society, ACM, ACM Special Interst Group on Architecture, AIAA, America Radio Relay League

10. Awards: 1994 NPS Space Systems Group Research Recognition Award

11. Courses taught (all are day courses):

Winter 95	EC4870, VLSI Systems Design (3-2) (graduate course)
Fall 95	EC2210, Electronics Engineering II (3-2) (undergraduate course)
	SS3035 Microprocessors for Space Applications (3-2) (graduate course)

12. Other duties:

Member of Ph.D. Oral Screening Exam Committee
Member of Engineers/Ph.S. Written Screening Exam Committee
Member of Computer TAG
Member and Chairperson of Space Electronics TAG

Research

July 1995- Sep. 1997	Half time research, "Radiation Immune, High-Speed, Low-Power, Gallium Arsenide Logic a Memory Devices Using Low Temperature Grown Buffer Layers," sponsored by U.S. Nav SPAWAR/ONR/NSA.
Oct. 1992- Sep. 1995	Half time research, "Radiation-Tolerant, High-Speed, Gallium Arsenide Dynamic Logic," sponsor by U.S. Navy, SPAWAR.
Oct. 1990- Sep. 1992	Half time research, "Design Principles for Very High-Speed Circuits and Systems," sponsored NPS Research Initiation Program.

13. Programs attended to improve professional competence:

Attended short course on the design of radiation tolerant ICs at the 1994 IEEE Nuclear and Space Radiation Effects Conference.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Phillip E. Pace**, February 21, 1956

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, University of Cincinnati, August 1990
   M.S., Electrical Engineering, Ohio University, March 1985
   B.S., Electrical Engineering, Ohio University, March 1983

4. Number of years on faculty: 3

   Original appointment: Assistant Professor, August 1992
   Promotion: Associate Professor, July 1995

5. Related experience:

   1990-1992 Design Specialist, General Dynamics Corporation
   1983-1987 Member of the Technical Staff, Hughes Aircraft Company

6. Patent: "High Resolution Encoding Process for Analog-to-Digital Converters"

7. Not registered

8. Principal publications:

Journal Papers

Pace, P. E., Schafer, J., and Styer, D., "Optimal SNS Preprocessing for Folding ADCs," *IEEE Transactions on Circuits and Systems -- II: Analog and Digital Signal Processing*, to be published.

Pace, P. E., and Foster, C., "Numerical Modeling of Opto-Electronic Integrated Circuits," *Scientific Computing*, pp. 19-22, October 1994.

Pace, P. E., and Taylor, L. L., "False Alarm Analysis of the Envelope and Envelope Approximation GO CFAR Processor," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 30, pp. 848-864, 1994.

Pace, P. E., and Styer, D., "High Resolution Encoding Process for an Integrated Optical Analog-to-Digital Converter, *Optical Engineering*, Vol. 33, pp. 2638-2645, 1994.

Pace, P. E., Ramamoorthy, P., and Styer, D., "A Preprocessing Architecture for Resolution Enhancement in High-Speed ADCs," *IEEE Transactions on Circuit and Systems --II: Analog and Digital Signal Processing*, Vol. 41, pp. 373-379, 1994.

Pace, P. E., and Foster, C., "Beam Propagation Analysis of a Parallel Configuration of Mach-Zehnder Interferometers," *Optical Engineering*, Vol. 33, pp. 2911-2921, 1994.

Pace, P. E., Ramamoorthy, and Styer, D., "Resolution Enhancement Technique for Guided-Wave Analog-to-Digital Converters," *Electronic Letters*, Vol. 28, pp. 2174-2175, November 1992.

Pace, P. E., and Ramamoorthy, P. A., "Digital Signal Processing and Filter Synthesis Concepts for Applications in Spectroscopy," *Spectroscopy*, Vol. 5, pp. 37-45, November 1990.

Conference Proceedings/Abstracts/Presentations

Pace, P. E., and Schafer, J., "Decimation of Encoding Errors in an Optimum SNS Folding ADC," *Proceedings of the IEEE International Symposium on Circuits and Systems*, Seattle, WA, May 1995.

Pace, P. E., Nishimura, Cooper, C. R., and Surratt, R. E., "Correlation of Anti-Ship Cruise Missile Simulator Experiments for High Confidence ECM Effectiveness Calculations (U)," *Proceedings of the Joint Western-Mountain Region EW Tech Symposium*, San Antonio, TX, April 1995.

Pace, P. E., Powers, J. P., Pieper, R. J., Walley, R., Yamakoshi, A., Crowe, C., and Nimri, B., "8-Bit Integrated Optical SNS ADC," *Proceedings of the 27th Southeastern Symposium on System Theory*, Starkville, MS, pp. 144-148, March 1995.

Pace, P. E., Ying, S. J., Powers, J. P., and Pieper, R. J., "Optical ΣΔ Analog-to-Digital Converters for High-Resolution Digitization of Antenna Signals," *Proceedings of the 5th ARPA Photonic Systems for Antenna Applications*, Naval Postgraduate School, January 1995.

Pace, P., Brewer, D., Taylor, L., Laulusa, G., and Butt, E., "Harbor Control Search Processing for Detection of Slow Moving Ships in Adverse Conditions," *Proc. of IEEE International Radar '95 Conf.*

Pace, P. E., Tigani, J., Dix, S., and Zwick, D., "Extraction of ASCM Threat Simulator Critical Parameters," SECRET-NOFORN presentation to the DoN Simulator Validation Working Group, Naval Research Laboratory, August 1994.

Pace, P. E., McGinnis, R., Lynch, C., and Cooper, C., "Advances in HIL and P-3/CCMP Correlation Processing," SECRET-NOFORN presentation to the Tactical Electronic Warfare Division, Naval Research Laboratory, June 1994.

Pace, P. E., and Brewer, D., "Comparison of Two Surface Mode Processors Using Arctic Salvor Sea Clutter Data," CONFIDENTIAL presentation to Hughes Missile Systems Company, April 1994.

Pace, P., McGinnis, R., and Cooper, R., "Algorithms for Assessing the Effectiveness of Shipboard Countermeasures Against Anti-Shipping Platforms, '' SECRET/NOFORN presentation to the Tactical Warfare Division, Naval Research Laboratory, March 1994.

Pace, P. E., and McGinnis, R., "Shipboard Countermeasures and Anti-Shipping Platforms," SECRET-NOFORN presentation at NPS to CAPT Cassidy, USN, Dr. Coffey, and CDR Ranelli, USN, Naval Research Laboratory, March 1994.

Pace, P. E., and Foster, C. C., "High Resolution Direct Digitization of Multi-Gigahertz Antenna Signals," PSAA-III, 3rd Annual Darpa Symposium on Photonic Systems for Antenna Applications, Naval Postgraduate School, Monterey, CA, January 22, 1993.

Pace, P., Pieper, R., Powers, J., Van de Veire, R., and Foster, C., "Feasibility Demonstration of a High-Resolution Integrated Optical Analog-to-Digital Converter," PSAA-IV, 4th Annual Darpa Symposium on Photonic Systems for Antenna Applications Naval Postgraduate School, Monterey, CA, January 1994.

Pace, P., Pieper, R., Powers, J., Van de Veire, R., Foster, C., Walley, R., and Yamakoshi, H., "Feasibility Demonstration of a High-Resolution Integrated Optical Analog-to-Digital Converter,'' presentation at NPS to CMDR R. Bowdish and Dr. Lovegrove, Space and Naval Warfare Systems Command, January 1994.

Pace, P. E., and Brewer, D., "Phalanx Surface Mode Block I LPF 4-Pole Canceler Analysis," presentation to Hughes Missile Systems Company, November 1993.

Additional ten papers prepared during 1990-1993.

Technical Reports (Additional 7 reports prepared during (1990-1992)

Pace, P. E., "8-Bit Integrated Optical Guided-Wave Analog-to-Digital Converters," NPS Interim Technical Report, to the Space and Naval Warfare Systems Command, October 1994.

Pace, P. E., "HIL and P-3/CCMP Correlation Processing (U)," SECRET/NOFORN NPS Interim Technical Report, to the Tactical Electronic Warfare Division, Naval Research Laboratories, September 1994.

Pace, P. E., "16-Bit Inverse MTI for Low Velocity Target Acquisition (U)," CONFIDENTIAL NPS Interim Technical Report EC-93-023, to Hughes Missile Systems Company, Jan. 1994.

9. Society member: Eta Kappa Nu, IEEE, SPIE, AOC

10. Awards: Naval Postgraduate School Outstanding Research Achievement Award (Electronic Warfare Academic Grou 1993, 1994), (Department of Electrical and Computer Engineering, 1994).

11. Courses taught (all courses are graduate level day courses)

Winter 95	EO4602, Electro-Optic Systems and Countermeasures (3-0)
Spring 95	EC4670, Electronic Warfare Systems (3-3)
Spring 94	EC4670, Electronic Warfare Systems (3-3)
Winter 93	EO3802, Electronic Warfare Computer Applications (3-2)
Spring 93	EC4670, Electronic Warfare Systems (3-3)

12. Other duties: Member, ECE Curriculum Committee (1 hr/week), Distance Learning Committee (2 hrs/week)

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Rudolf Panholzer**, October 28, 1928

2. Academic rank: Professor (full time)

3. Degrees:

   DSc. Tech., University, Graz, Austria, 1961
   Engineer, Electrical Engineering, Stanford University, Stanford, CA, 1957
   M.S.E.E., Stanford University Stanford, CA, 1955
   Diplom Ingenieur, Tech. University Graz, Austria, 1953

4. Number of years on faculty: 30

   Original Appointment: Associate Professor, January 1964
   Promotion: Full Professor, April 1968

5. Related experience:

   1969-1970 Staff Scientist, Cintra Inc., Mountain View, CA

6. Consulting/patents: Consulting for numerous semiconductor companies in Silicon Valley (1969-1985).

7. Not Registered

8. Principal publications: None in the past five years.

9. Society member: IEEE, ASEE

10. Awards: None

11. Courses taught (all courses are day courses):

    Winter 95: EO3513, Communications Systems Engineering (4-2) (graduate course)
    EC2500, Communications Systems (3-2) (undergraduate course)

12. Other duties:

    Chairman, Space Systems Academic Group
    Research work

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not Applicable

1. Name and date of birth: **Ron J. Pieper**, April 21, 1951

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical and Computer Engineering, University of Iowa, Iowa City, IA, 1984
   M.S., Electrical and Computer Engineering, University of Wisconsin, Madison, WI, 1979
   M.S., Physics, University of Wisconsin, Madison, WI, 1976
   B.S., Physics (Magna Cum Laude), University of Missouri, St. Louis, MO, 1974

4. Number of years on faculty: 5

   Original appointment: Associate Professor, 1990

5. Related experience:

1985-1990	Assistant Professor, Virginia Polytechnic Institute and State University
1984-1985	Visiting Asst. Professor, Dept. of Electrical and and Computer Engineering, University of Io
1987	Visiting Faculty Fellow, U.S. Army, Center for Night Vision (summer) and Electro-optics, Belvoir, VA
1979-1980	Device Process Engineer, Mostek, Carrolton, TX

6. Patents/consulting: None

7. Registered in Virginia, #020024

8. Principle publications:

Journal Papers

Pieper, R. J., Richstein, J. K., Poon, T.-C., and Moore, D. J., "Real-Time Histogram Generation Using Active Optical Scanning," *Optics and Laser Technology*, accepted for publication.

Pieper, J. R., and Nassapoulos, A., "A Conceptually Simple Method for Obtaining Ray Equations in Optical Fibers," *IEEE Transactions on Education*, accepted for publication.

Pendergraft, K., and Pieper, R., "An Exact Solution for a Reflection Coefficient in a Medium Having an Exponential Impedance Profile," *Journal of the Acoustical Society*, Vol. 94, No.1, pp. 580-582, 1993.

Pieper, R. J., Raj, K., and Poon, T-C., "A Visibility Dependent Depth of Focus for Incoherent Sinusoidal Sources," *Applied Optics*, Vol. 31, No. 7, pp. 977-986, March 1992.

Duncan, D. B., Poon, T.-C., and Pieper, R. J., "Real-Time Nonlinear Image Processing Using an Active Optical Scanning Technique," *Optics and Laser Technology*, Vol. 3, No. 1, pp. 19-23, 1991.

Pieper, R. J., and Poon, T. C., "Optical Transfer Functions for Deforcused Two-Pupil System," *Journal of Modern Optics*, Vol. 37, No. 12, pp. 2055-2072, 1990.

Pieper, R. J., and Poon, T. C., "System Characterization of Apodized Acousto-Optic Bragg Cells," *Journal of the Optical Society of America*, Vol. 7, pp. 1751-1758, September 1990.

Duncan, B. D., Poon, T. C., and Pieper, R. J., "Real-Time Nonlinear Image Processing Using an Active Optical Scanning Technique," *Optics and Laser Technology*, December 1990.

Conference Proceedings/Abstracts/Presentations

Pieper, R. J., and Kraus, A. D., "Cold Plates with Asymmetric Heat Loading: Part I -- The Single Stack," *Proc.of ASME InterPack'95 Conf., Adv. in Elec. Packaging*, Vol. 10-2, ASME, pp. 865-870, 1995.

Pieper, R. J., and Kraus, A. D., "Cold Plates with Asymmetric Heat Loading: Part II -- The Double Stack," *Proc. of ASME InterPack'95 Conf., Adv. in Elec. Packaging*, Vol. 10-2, ASME, pp. 871-876, March 1995.

Pace, P. E., Ying, S., Powers, J. P., and Pieper, R. J., "Optical Σ-Δ Analog-to-Digital Converters for High-Resolution Direct Digitization Antenna Signals," Photonics Systems for Antenna Applications, PSAA-V, to be published.

Pieper, R., Cooper, A., and Pelegris, G., "Dual Baseline Triangulation," *Proceedings of the 27th Southeastern Symposium on System Theory*, pp. 424-428, March 1995.

Pieper, R. J., "8-Bit Integrated Optical SNS ADC," *Proceedings of 27th Southeastern Symposium on System Theory*, pp. 144-148, March 1995.

Pieper, R. J., Pace, P. E., Powers, J. P., Van de Veire, R., Foster, C. C., Walley, R., and Yamakoshi, H., "Feasibility Demonstration of a High-Resolution Integrated Optical Analog--to--Digital Converter," presentation and in *Proceedings of the 4th Annual ARPA Symposium on Photonic Systems for Antenna Applications*, ARPA/TIO, Arlington VA, pp. 323–328, 1994.

Pieper, R. J., and Cooper, A. W., "A Visibility Model for MRTD Prediction, SPIE's Infrared Imaging Systems: Design, Analysis, Modeling and Testing V," Vol. 2224, pp. 258-269, April 1994.

Abbott, W., III, Kay, R., and Pieper, R., "Performance Considerations for the Application of the Lossless Browse and Residual Model," NASA's 1994 Space and Earth Science Data Compression Workshop, pp. 43-54, April 1994.

Pieper, R. J., Richstein, J. K., Ho, C. M., Lee, A., and Poon, T. C., "Real-Time Histogram Generation Using Optical Scanning," 26th Southeastern Symposium on System Theory, pp. 310-315, March 1994.

Richstein, J. K., Fouts, D. J., Pieper, R. J., Poon, T. C., "A CMOS VLSI IC For Real-Time Opto-Electronic Two-Dimensional Histogram Generation," *Proceedings of the 26th IEEE Southeastern Symposium on System Theory*, Athens, Ohio, pp. 390-394, March 1994.

Richstein, J. K., Pieper, R. J., Ho, C.-M., Lee, A., and Poon, T.-C., "Real-Time Histogram Generation Via Laser Scanning," presentation and in *Proceedings of the Optical Society of America, National Meeting*, Toronto, Canada, October 1993.

Nassopoulos, A., and Pieper, R., "A Heuristic Approach to the Computation of 3D-Ray Trajectories in Step-Index Optical Fibers", presentation and in *25th IEEE Southeastern Symposium on System Theory Proceedings*, pp. 179-183, March 1993.

Pieper, R., and Poon, T.-C., "Frequency-Dependent Optical Beam Distortion Generated by Acousto-Optic Bragg Cells," presented at the SPIE/SPEE Symposium on Electronic Imaging, Beam Deflection and Scanning Technologies, SPIE, Vol. 1454, pp. 324-335, February 1991.

Poon, T. C., and Pieper, R. J., "Novel Approach to Real-Time Joint Fourier Transform Correlation," presentation, *Proceedings of the 15th Congress of the International Commission of Optics, Conference on Optics in Complex Systems*, Federal Republic of Germany, SPIE Vol. 1319, p. 641, August 1990.

Thirteen additional conferences papers during 1990-1992.

Technical Reports (three reports prepared during 1993-1994)

9. Society member: Institute of Electrical and Electronic Engineers (Senior Member), Optical Society of America (OSA International Society for Optical Engineers (SPIE), Society of Professional Engineers (PE)

10. Awards: None

11. Courses taught (all courses are graduate level day courses):

Summer 95	EO3523, Communication Systems Analysis (3-0)
Winter 95	EC4210, Electro-Optic Systems Engineering (3-0)
Fall 95	EC3550, Fiber Optic Systems Fundamentals (3-1) (2 sections)

12. Other duties:

Academic Associate, advising for U.S. non-Navy (8 hours per week).
Thesis Advisor (8 hours per week).
Lab development for EC2500. Lab procedures developed in 1992-1993 in cooperation with assistance from our circuit technician, Mr. Jeff Knight, are being used for EC2500.

Research:

Spring 95	Full time research, Generation Thermal Imaging Systems, sponsored by NRL and High Resoluti Direct Digitization and Optical Telemetry of Antenna Signals, sponsored by SPAWAR.
Spring 94	Full time research, Generation Thermal Imaging Systems, sponsored by NRL and High Resoluti Direct Digitization and Optical Telemetry of Antenna Signals, sponsored by SPAWAR.

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **John P. Powers**, December 28, 1943

2. Academic rank: Professor and Dean of Faculty (full-time)

3. Degrees:

   Ph.D., Electrical Engineering, University of California, Santa Barbara, July 1970
   M.S., Electrical Engineering, Stanford University, June 1966
   B.S., Electrical Engineering, Tufts University, Medford, MA, June 1965

4. Number of years on faculty: 24

   Original appointment: September 1970
   Promotion: Associate Professor and tenured, July 1976
   Promotion: Professor, July 1982

5. Related experience:

1975-1975	Exchange Scientist, University of Paris VI
1966-1970	Research Assistant, UC Santa Barbara
1964 & 1965	Summer engineer, Mitre Corporation

6. Consulting: None

7. Registration: None

8. Principal publications:

Book

Powers, J. P., *Introduction to Fiber Optic Systems*. Richard D. Irwin, Inc., and Aksen Associates, 1993. (ISBN 0-256-12996-7)

Chapters in Books

Bahl, R., and Powers, J. P., "A Simulation Study of 3D Image Generation Using Fan-Beam Sonars," *Acoustic Imaging*, Vol. 19, E. Emert and H.-P. Harjes, Eds., pp. 873-878, Plenum Publishing, New York, 1992.

Powers, J. P., Reid, W., Upton, J., and Van de Veire, R., "A Comparison of the Transient Propagation Properties of Bessel and Gaussian Waves," to be published in *Acoustic Imaging*, Vol. 21, J. P. Jones, Ed., Plenum Publishing, New York.

Conference Proceedings/Abstracts/Presentations

Pace, P. E., Ying, S. J., Powers, J. P., and Pieper, R. J., "Optical $\Sigma\,\Delta$ Analog-to-Digital Convertors for High-Resolution Digitization of Antenna Signals," to be published in *Proceedings of the 5th Annual ARPA Symposium on Photonic Systems for Antenna Applications*, ARPA/TIO, Arlington, VA, 1995.

Pace, P. E., Powers, J. P., Pieper, R. J., Walley, R., Yamakoshi, H., Crowe, C., and Nimri, B., "8-Bit Integrated Optical SNS ADC," *Proceedings of the 27th Southeast Symposium on System Theory*, IEEE Computer Society Press, pp. 144-148, 1995.

Pieper, R. J., Pace, P. E., Powers, J. P., Van de Viere, R., and Foster, C. C., "Feasibility Demonstration of a High-Resolution Integrated Optical Analog-To-Digital Converter," *Symposium Digest of the 4th Annual ARPA Symposium on Photonic Systems for Antenna Applications*, pp. 323-328, January 1994.

Pieper, R. J., Pace, P. E., Powers, J. P., Van de Veire, R., Foster, C. C., Walley, R., and Yamakoshi, H., "Feasibility Demonstration of a High-Resolution Integrated Optical Analog--to--Digital Converter," *Proceedings of the 4th Annual ARPA Symposium on Photonic Systems for Antenna Applications*, ARPA/TIO, Arlington VA, pp. 323–328, 1994.

Powers, J. P., and Netzer, D. W., "Automatic Particle Sizing from Rocket Motor Holograms, presentation and in *Practical Holography VI (1992)*, SPIE Vol. 1667, SPIE, Bellingham WA, pp. 136-145, 1992.

Powers, J., "Acousto-Optic Signal Processing," presented to the ECE Department, University of Pittsburgh.

Powers, J. P., Harvey, J. P. and Marinsalta, D., "Acousto-Optic Channelizer Study," *Proceedings of the 1990 IEEE Ultrasonics Symposium*, B. R. McAvoy, Ed., IEEE Press, New York, pp. 689-692, 1991.

Bahl, R. and Powers, J., "A Simulation Study of 3D Image Generation Using Fan-Beam Sonars," presented at the 20th International Symposium on Acoustical Imaging, Bochum, Germany, April 1991.

Powers, J. P., Harvey, J. P., and Marinsalta, D., "Acoustooptic Channelizer Study," IEEE Ultrasonics Symposium, Honolulu, December 1990 (Poster paper presented at plenary session, about 200 session attendees).

Technical Reports

Pace, P. E., Pieper, R. J., and Powers, J. P., High-Resolution Direct Digitization and Optical Telemetry of Shipboard Antenna Signals, NPS Technical Report EC-94-016, December, 1994.

Powers, J. P., "Acoustic Propagation Modeling Using MATLAB," NPS Technical Report EC-93-014, 1 September 1993.

Powers, J., "Automatic Particle Sizing from Rocket Motor Holograms," NPS Technical Report EC-91-003, 1990.

Bahl, R., and Powers, J., "Computer Model of a High-Resolution Imaging Sonar," NPS Technical Report EC-90-011, 1990.

Other

(Software Program) Powers, J. P., "SEMEX -- A Progam to Extract Particle Size Information from Scanning Electron Microscope Images," available from NIST (Acquisition No. AD-M000 110; Report number DOD/SW/DK-93/056).

9. Society member:

IEEE: Laser and Electo-optics Society, Education Society, Ultrasonics Society
Optical Society of America
Acoustical Society of America
SPIE - The Optical Engineering Society

10. Awards:

NPS Sigma Xi Chapter Menneken Research Award - 1987
NSF Assistantship 1965-66
BSEE Summa cum Laude 1965

11. Courses taught: No courses (full-time NPS administrator)

12. Other duties: 90% NPS administration, 10% reimbursable research

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Ralph Clark Robertson**, July 25, 1950

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, University of Texas, Austin, TX, 1983
   M.S., Electrical Engineering, University of Texas, Austin, TX, 1980
   B.S., Electrical Engineering, Texas Tech University, Lubbock, TX, 1973

4. Number of years on faculty: 6

   Original appointment: Associate Professor, June 1989
   Award of Academic Tenure, July 1993

5. Related experience:

1983-1989	Assistant Professor, Virginia Polytechnic Institute and State University
1984 (summer)	Summer Faculty Fellow, NASA/Johnson Space Center, Houston, TX. Develop infrared communications link for space shuttle experiment.
1983 (summer)	Summer Faculty Associate, IBM Corporation, Austin, TX. EMI measurement and suppression.
1973-1979	Senior Associate Engineer, IBM Corporation, Austin, TX. Electronic circuit designer.

6. Consulting/patents: None

7. Not registered

8. Principal publications:

Journal Papers

Robertson, R. C., Ha, T. T., and Banh, D. V., Effect of Capture on Throughput of Variable Length Packet Aloha Systems, *Computer Communications*, Vol. 17, pp. 836-842, December 1994.

Anderson, G. L., Robertson, R. C., Peterson, B. L., and Dillard, D. A., Embedded Piezoelectric Sensors to Measure Peel Stresses in Adhesive Joints, *Experimental Mechanics*, Vol. 34, pp. 194-201, Sep. 1994.

Robertson, R. C., and Lee, K. Y., "Performance of Fast Frequency-Hopped MFSK Receivers with Linear and Self-Normalization Combining in a Rician Fading Channel with Partial-Band Interference," *IEEE Journal on Selected Areas in Communications*, Vol. 10, No. 4, pp. 731-741, May 1992.

Robertson, R. C., and Ha, T. T., "Error Probabilities of Fast Frequency-Hopped FSK with Self-Normalization Combining in a Fading Channel with Partial-Band Interference," *IEEE Journal on Selected Areas in Communications*, Vol. 10, No. 4, pp. 714-723, May 1992.

Robertson, R. C., and Ha, T. T., "A Model for Local/Mobile Radio Communications with Correct Packet Capture," *IEEE Transactions on Communications*, Vol. 40, No. 4, pp. 847-854, April 1992.

Robertson, R. C., and Ha, T. T., "Error Probabilities of Fast Frequency-Hopped MFSK with Noise-Normalization Combining in a Fading Channel with Partial-Band Interference," *IEEE Transactions on Communications*, Vol. 40, No. 2, pp. 404-412, February 1992.

Varnum, K. C. M., and Robertson, R. C., "Error Probabilities of Coherent Optical Heterodyne FSK--CDMA Signals in a Noncoherent Detection System Degraded by Laser Phase Noise," *Journal of Optical Communications*, Vol. 13, No. 3, pp. 85-92, September 1992.

Conference Proceedings/Abstracts/Presentations

Kragh, M., Sheltry, J., and Robertson, R. C., "The Effect of Ricean Fading and Partial-Band Interference on Linear and Noise-Normalized Fast Frequency-Hopped MFSK Constant Energy/Hop Receivers," presentation, *Proc. of the IEEE Military Communications Conf.*, Vol. 3, pp. 987-991, Oct. 2-5, 1994.

Chua, A. Y. P., Ha, T. T., and Robertson, R. C., "Error Probabilities for FFH/BFSK with Noise Normalization and Soft Decoding in a Fading Channel with Partial-Band Jamming," presentation and in *Proceedings of the IEEE Military Communications Conference*, Vol. 2, pp. 448-452, October 2-5, 1994.

Chua, A. Y. P., Ha, T. T., and Robertson, R. C., "Error Probabilities for FFH/BFSK with Ratio-Statistic Combining and Soft Decoding in a Fading Channel with Partial-Band Jamming," presentation, *Proc. of IEEE Asilomar Conf. on Signals, Systems, and Computers*, Vol. 1, pp. 460-464, Oct. 31-Nov. 2, 1994.

Robertson, R. C., and Morgan, M. A., "Ultra-Wideband Impulse Receiving Antenna Design and Evaluation," 2nd International Conference on Ultra-Wideband, Short-Pulse Electromagnetics, Polytechnic University, New York, April 5-7, 1994.

Morgan, M. A., and Robertson, R. C., "Loaded TEM Horn Antenna for Ultra-Wideband Signal Reception," presentation and in *Abstracts of URSI Radio Science Meeting*, p. 490, 1994.

Kragh, M., and Robertson, R. C., "The Effect of Rician Fading and Partial-Band Interference on Noise-Normalized, Fast Frequency-Hopped MFSK Receivers," presentation and in *Proceedings of IEEE Military Communications Conference*, Vol. 1, pp. 182-186, 1993.

Varnum, K. C. M., and Robertson, R. C., "Error Probabilities of Optical Heterodyne OOK and FSK Communications Systems," presentation and in *Proceedings of IEEE Global Telecommunications Conference*, Vol. 3, pp. 1896-1900, 1993.

Robertson, R. C., Vece, T. W., and Ha, T. T., "Performance of a Fast Frequency-Hopped DFT-Based MFSK Receiver with Noise-Normalization Combining in a Fading Channel with Partial-Band Interference," presentation and in *Proceedings of IEEE Military Communications Conference*, Vol. 1, pp. 48-52, 1992.

Robertson, R. C., Riley, J. F., and Ha, T. T., "Error Probabilities of Fast Frequency-Hopped FSK with Ratio-Statistic Combining in a Fading Channel with Partial-Band Interference," presentation and in *Proceedings of IEEE Military Communications Conference*, Vol. 3, pp. 865-869, 1992.

Robertson, R. C., and Lee, K. Y., "Performance of Fast Frequency-Hopped MFSK Receivers with Linear Combining in a Rician Fading Channel with Partial-Band Interference," presentation and in *Proc. of IEEE Asilomar Conf. on Signals, Systems, and Computers*, Vol. 2, pp. 851-855, Nov. 4-6, 1991.

Varnum, K. C. M., and Robertson, R. C., "Error Probabilities of Coherent Optical Heterodyne FSK-CDMA Signals in a Noncoherent Detection System Degraded by Laser Phase Noise," presentation and in *Proc. of IEEE Asilomar Conf. on Signals, Systems, and Computers*, Vol. 2, pp. 878-882, Nov. 4-6, 1991.

Robertson, R. C., and Ha, T. T., "A Model for Local/Mobile Radio Communications with Variable Length Packets," presentation, *Proc. of 1991 IEEE Military Communications Conf.*, Vol. 1, pp. 182-186, 1991.

Varnum, K. C. M., Robertson, R. C., and Ha, T. T., "Error Probabilities of Coherent Optical Heterodyne OOK Signals in a Noncoherent Detection System Degraded by Laser Phase Noise," presentation and in *Proceedings of the 1991 IEEE Global Telecommunications Conference*, Vol. 3, pp. 1596-1600, 1991.

Six additional conference papers published during 1990.

Technical Reports (five reports prepared during 1993)

9. Society member:

Institute of Electrical and Electronics Engineers (IEEE), Senior Member: Communications Society, Antennas a
Propagation Society
International Union of Radio Science (URSI), Commission F
Eta Kappa Nu (HKN), Tau Beta Pi

10. Awards: Naval Postgraduate School Outstanding Instructional Contribution Award, Department of Electrical a Computer Engineering (1991), Electronic Warfare Academic Group (1991)

11. Courses taught (all courses are graduate level day courses):

Fall 94	EC4550, Digital Communications (4-0)
Winter 94	EC3510, Communications Engineering (3-1)
Summer 94	EC4560, Communications ECCM (3-2)
Fall 95	EC4550, Digital Communications (4-0)

12. Other duties:

Academic Associate (3 hours per week), 1 course release time.
Associate Chairman -- Students (2 hours per week), salary compensation.
Short course preparation/presentation for NSWC, Dahlgren (1/8 time).
Research for U.S. Army CECOM: Ultra wideband impulse antenna design (1/4 time).

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **D. Curtis Schleher,** May 16, 1932

2. Academic rank: Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, Polytechnic University, 1975
   M.S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1958
   B.S., Electrical Engineering, Polytechnic Institute of Brooklyn, 1954

4. Number of years on faculty: 1.5

5. Related experience:

   Industrial

1991-1994	Vice President of Engineering, Telephonics, NY
1980-1994	Director of Research and Development, Eaton, NY
1977-1980	Manager, Advanced Development Laboratories, Raytheon, MA
1954-1980	Department Manager, AIL, NY

   Teaching

1984-1995	Short courses on engineering

   Academic

1990-1995	ABET Evaluator

6. Consulting: Various for Ericsson, Telephonics, Martin Marietta

7. Not registered

8. Principal publications:

   Books

   Schleher, D. C., *Introduction to Electronic Warfare*, Norwood, MA: Artech, 1994.

   Schleher, D. C., *MTI and Pulsed Doppler Radar*, Norwood, MA: Artech, 1991.

   Journal Paper

   Schleher, D. C., "Solving Radar Detection Problems Using Simulation," *IEEE AES Magazine*, May 1995.

   Conference Proceedings/Abstracts/Presentations

   Schleher, D. C., "Periscope Detection Radar," IEEE International Radar Conference, Washington DC, May 1995.

   Schleher, D. C., "Small Target Detection in K-Distributed Clutter," IEEE Radar Signal Processing Conference, Melville, NY, April 1994.

9. Society member:

   IEEE, Fellow
   IEEE Aerospace and Electronics Society
   IEEE Signal Processing Society
   Old Crows Association

10. Honors and Awards:

    Eta Kappa Nu
    Sigma Xi
    IEEE Fellow, 1986
    Chairman, Awards Committee, L. I. Section IEEE

11. Courses taught (all courses are graduate level day courses):

Summer 95	EO3402, Signal Processing Systems (4-1)

Spring 95	EC4010, Principles of Systems Engineering (3-1)
Winter 94	EO3402, Signal Processing Systems (4-1)
	EO4622, Electronic Warfare Systems (3-2)
Spring 94	EC4010, Principles of Systems Engineering (3-1)
Summer 94	EO3402, Signal Processing Systems (4-1)

12. Other duties:

Member, Academic Council
Member, EW Academic Group
Member, Joint Warfare Analysis Committee

Coordinator for Short Courses on Systems Engineering and Radar
Thesis Advisor for 4 master's students
Doctoral Committee for 1 Ph.D. student
Lecture on Radar and EW for Technical Refresher Course

13. Programs attended to improve professional competence:

1990-1995	Reviewer for *IEEE AES Transactions*
1993	Seminar on Total Quality Management
1991	Seminar on Independent Research and Development

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Michael K. Shields**, March 6, 1959

2. Academic rank: Military Assistant Professor (full time)

3. Degrees:

   Ph.D., Naval Postgraduate School, Monterey, CA, 1991
   B.S., Electrical Engineering, United States Naval Academy, Annapolis, MD, 1981

4. Number of years on faculty: 3

   Original appointment: Military Assistant Professor

5. Related experience:

   Naval service: Commissioned May 1981

   Duty stations:

1989-1992	Chief Engineer, USS Lewis and Clark, SSBN-653
1986-1989	Naval Postgraduate School
1983-1986	USS Ray, SSN-653
1981-1983	Naval Nuclear Engineering Training

6. Consulting/patents: Consulting experience in digital signal processing of communications signals.

7. State in which registered: None

8. Principal publications:

   Journal Paper

   Therrien, C. W. and Shields, M. K., "A Signal Classification Technique Using Hidden Markov Models," *U.S. Navy Journal of Underwater Acoustics*, Vol. 40, No. 4, September 1991.

   Conference Proceedings/Abstracts/Presentations

   Therrien, C. W., Shields, M. K., "Transient Classification Using Markov Methods," in the *Proceedings of the Oceans 90 Conference*, Arlington, VA, September 1990.

   Therrien, C. W., and Shields, M. K., "A Hidden Markov Model Approach to the Classification of Acoustic Transients," presentation and in the *Proceedings of the 1990 International Conference Acoustics, Speech, and Signal Processing*, Albuquerque, NM, April 1990.

9. Society member: Sigma Xi, IEEE

10. Awards: None

11. Courses taught (all courses are graduate level day courses):

Spring 95	EO3513, Communications Systems Engineering (4-2)
	EC3410, Discrete Time Random Processes (3-1)
Winter 95	EC4930, Digital Signal Processing Hardware (3-2)
Fall 95	EO3523, Communications Systems Analysis (4-2) (3 sections)

12. Other duties:

    Thesis advising (4 hours per week)
    Military duties (4 hours per week)
    C3 Academic Group (2 hours per week)

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Shridhar B. Shukla**, January 5, 1962

2. Academic rank: Assistant Professor (full time)

3. Degrees:

   Ph.D., Computer Engineering, North Carolina University, Raleigh, NC, November 1990
   M.S., Electrical Engineering, Virginia Tech, Blacksburg, VA, August 1985
   B.Tech., Electrical Engineering, Indian Institute of Technology, Bombay, India, June 1983

4. Number of years on faculty: 5.5

   Original appointment: Assistant Professor, January 1990

5. Related experience: None

6. Consulting/patents: None

7. Not registered

8. Principal publications:

Journal Papers

Shukla, S. B., and Agrawal, D. P., A Framework for Mapping Periodic Real-time Applications On Multicomputers, *IEEE Transactions on Parallel and Distributed Computing*, Vol. 5, No. 7, 1994.

Stone, L. C., Shukla, S. B., and Neta, B., Parallel Satellite Orbit Prediction Using a Workstation Cluster, *Computers Mathematical Applications*, Vol. 28, No. 8, Elsevier Science, Pergamon Press, 1994.

Healey, A., McGhee, R., Cristi, R., Papoulias, F., Kwak, S., Kanayama, Y., Lee, Y., Shukla, S., and Zaky, A., "Research on Autonomous Underwater Vehicles at the Naval Postgraduate School," *Naval Research Reviews*, Vol. XLIV, No. 1, 1992.

Conference Proceedings/Abstracts/Presentations

Shukla, S. B., Little, B., and Zaky, A., "A Compile-time Technique for Controlling Real-time Execution of Task-level Data-flow Graphs," presentation, International Conference on Parallel Processing, St. Charles, Illinois, August 1992. Won the Outstanding Paper Award. (Approximately 100 people attended the presentation out of approximately 450 registered for the conference.)

Shukla, S. B., and Agrawal, D. P., "Task Allocation in Distributed Memory Multiprocessors for Periodic Real-Time Applications," presented at the 20th International Conference on Parallel Processing, St. Charles, IL, August 1991.

Shukla, S. B., and Agrawal, D. P., "Scheduling Pipelined Communication in Distributed Memory Multiprocessors for Real-Time Applications," presented at the 18th Annual International Symposium in Computer Architecture, Toronto, Canada, May 1991.

Shukla, S. B., Ramakrishnan, V., and Agrawal, D. P., "A Pipelined Architecture for Online Low Level Vision," presentation and in *Proceedings of the Euromicro Workshop on Real-time Systems*, Horsholm, Denmark, pp. 198-204, June 1990.

Agrawal, D. P., Shukla, S. B., and Ramakrishnan, V., "A Real-time Component Labeling Algorithm and Its Architectural Mapping," presenated at the Parallel Computing (PARCOM) 90 Conference, sponsored by Center for Development of Advanced Computing, Pune, India, December 10-11, 1990.

Technical Reports

Shukla, S. B., Design Requirements for the Common Data Link's Network Interface, NPS Technical Report EC-94-011, October 1994.

Shukla, S. B., Boyer E., and Klinker E., Multicast Tree Construction in Network Topologies with Asymmetric Link Loads, NPS Technical Report EC-94-012, September 1994.

Shukla, S. B., and Raghuram, D., "Group Membership In Asynchronous Distributed Environments Using Logically Ordered Views," NPS Technical Report, EC-92-009, September 1992.

Shukla, S. B., Little, B., and Zaky, A., "Real-Time Execution Control of Task-Level Data-Flow Graphs Using A Compile-time Approach," NPS Technical Report, EC-92-007, April 1992.

Little, B. S., and Shukla, S. B., "A Technique for Predictable Real-Time Execution in the AN/UYS-2 Parallel Signal Processing Architecture," NPS Technical Report EC-92-002, December 1991.

9. Society member: IEEE, ACM

10. Awards:

1993 National Science Foundation, Research Initiation Award
1992 International Conference on Parallel Processing Outstanding Paper Award

11. Courses taught (all courses are graduate level day courses):

Fall 95	EC3850, Computer Communication Methods (3-0)
Summer 94	EC4850, High Speed Networking (3-2)
	EC4810, Fault Tolerant Computing (3-2)
Spring 94	EC3850, Computer Communication Methods (3-0)
	EC4570, Detection and Estimation Theory (4-1)

12. Other duties (1 hour per week)

Chair, Academic Computing Committee
Reviewer, *IEEE Transactions on Computers*

Research:

Spring 95	Full time research, sponsored by National Science Foundation and the Defense Airborn Reconnaissance Group (40 hours per week)
Winter 95	Full time research, sponsored by National Science Foundation and the Defense Airborn Reconnaissance Group (40 hours per week)

13. Programs attended to improve professional competence:

Enterprise Systems Management Tutorial, October 1994.
ISIS Distributed System Course, Cornell University, 1993.

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Rasler W. Smith**, March 13, 1952

2. Academic rank: Instructor (half-time)

3. Degrees:

   Electrical Engineer, Naval Postgraduate School, March 1990
   M.S., Electrical Engineering, Naval Postgraduate School, March 1990
   B.S., Electrical Engineering, University of Texas, December 1979

4. Number of years on faculty: 1

   Original appointment: Instructor, February 1994

5. Related experience:

1992-1993	Systems Engineer, BTG Inc.
1990-1992	Senior Command Engineer, MCTSSA Camp Pendleton

6. Consulting/patents: None

7. Not registered

8. Principal publication:

   Engineer's thesis, "Ionospheric Effects on Precision Frequency Measurement," Naval Postgraduate School, March 1990.

9. Society member: Eta Kappa Nu

10. Awards: None

11. Courses taught (all courses are undergraduate day courses)

Summer 94	EC2450, Accelerated Linear Systems (4-0)
Spring 94	EC2500, Communications Theory (3-2)

12. Other duties:

    Research:

Spring 95	Full time research, sponsored by NSG
Winter 95	Full time research, sponsored by NSG
Fall 94	Full time research, sponsored by NSG
Summer 94	Half time research, sponsored by NSG
Spring 94	Half time research, sponsored by NSG

13. Programs attended to improve professional competence:

    HF Radio Systems and Techniques International Conference, 1994
    Beyond Line of Site Conference, 1994
    International Symposium on Equatorial Aeronomy, 1995

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Frederick W. Terman**, March 10, 1929

2. Academic rank: Senior Lecturer (full time)

3. Degrees:

   M.S., Electrical Engineering, Stanford University, Stanford, CA, June 1950
   B.S., Engineering Science, Stanford University, Stanford, CA, June 1949

4. Number of years on the faculty: 19

   Original appointment: Assistant Professor, June 1964
   (Employed elsewhere from June 1972 to September 1984)
   Appointment as Adjunct Teaching Professor: September 1984
   Appointment as Visiting Associate Professor: September 1993
   Appointment as Senior Lecturer: September 1994

5. Related experience:

1979-1984	Lecturer in Engineering at the level of Associate Professor, teaching half time in Engineering ar half time in Computer Science, San Francisco State University, San Francisco, CA.
1978	Lecturer in Electrical Engineering, Stanford University, Stanford, CA.
1977	Lecturer in Computer Science, Stanford University, Stanford, CA.
1960-1964	Assistant Professor of Physics, Adelphi University, Garden City, NY.
1960	Special Lecturer in Electrical Engineering, Newark College of Engineering, Newark, NJ.
1958-1959	Member of the Technical Staff, Bell Telephone Labs, Murray Hill, NJ.

6. Consulting/patents: None

7. Not registered

8. Principal publications: No publications in last five years.

9. Society Member:

   Institute of Electrical and Electronics Engineers
   IEEE Computer Society
   ACM
   American Association of Physics Teachers

10. Awards:

    B.S. with "Great Distinction"
    Elected to Tau Beta Pi and Phi Beta Kappa at Stanford University
    Elected to Sigma Xi at Harvard University

11. Courses taught (all course are day courses):

Winter 95:	EO3816, Computer Architectures for Military Applications (3-0) (graduate course)
	EC3840, Introduction to Computer Architecture (3-1) (graduate course)
Fall 94:	EC2820, Digital Logic Circuits (3-2) (undergraduate course)
	EC4820, Advanced Computer Architectures (3-1) (graduate course)
Summer 94:	EC2800, Introduction to Microprocessors (3-2) (undergraduate course)
	EC3820, Computer Systems (3-1) (graduate course)
	EC4800, Advanced Topics in Computer Architecture (3-0) (graduate course)

12. Other duties (average 1 hour per week):

    Member of the ECE TAG-Computers, and Distance Learning Group.

13. Programs attended to improve professional competence:

    Spring CompCon, tutorials and conference, San Francisco, CA.
    Asilomar Microcomputer Workshop, Pacific Grove, CA.
    Hot Chips Symposium, tutorials and conference, Stanford, CA.
    Hot Interconnects Symposium, tutorials and conference, Stanford, CA.

14. Special duties of co-op faculty: Not Applicable

1. Name and date of birth: **Charles W. Therrien**, February 23, 1943

2. Academic rank: Professor (full time)

3. Degrees:

   Ph.D. Electrical Engineering, Massachusetts Institute of Technology, Cambridge, MA, June 1969
   Electrical Engineer, M.I.T., June 1966
   S.B. and S.M., Electrical Engineering, M.I.T., June 1965

4. Number of years on faculty: 11

   Original appointment: Associate Professor, August 1984
   Promotion: Professor, July 1989

5. Related Experience:

   1981-1982 Naval Postgraduate School, Adjunct Professor (on mobility assignment from Lincoln Laboratory)
   1973-1984 M.I.T. Lincoln Laboratory, Member of the technical staff

6. Consulting: None currently

7. Not registered

8. Principal Publications:

Books

Therrien, C. W., *Discrete Random Signals and Statistical Signal Processing*, Prentice-Hall Inc., Englewood Cliffs, NJ, 1992.

Therrien, C. W., *Decision, Estimation and Classification: An Introduction to Pattern Recognition and Related Topics*, John Wiley and Sons, New York, 1989.

Journal Papers

Therrien, C. W., Victory, C. W., and Pfeifer, G. K., Methods for Modeling Transient Sonar Data, *U.S. Navy Journal of Underwater Acoustics*, Vol. 44, No. 2, April 1994. [SECRET NOFORN]

Therrien, C. W., Rozwod, W. J., and Lim, J. S., "Design of 2-D FIR Filters by Nonuniform Sampling," *IEEE Transactions on Signal Processing*, Vol. 39, No. 11, November 1991.

Therrien, C. W. and Shields, M. K., "A Signal Classification Technique Using Hidden Markov Models," *U.S. Navy Journal of Underwater Acoustics*, Vol. 40, No. 4, September 1991.

Conference Proceedings/Abstracts/Presentations

Therrien, C. W., and Hashad, I., "Higher Order Statistics of the Discrete Wiener Model for Application in Nonlinear Process Modeling and Identification," *Proceedings of the 28th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, November 1994.

Therrien, C. W., Cristi, R., and Allison, D. E., "Methods for Acoustic Data Synthesis," IEEE DSP Workshop, Yosemite National Park, California, October 1994.

Therrien, C. W., Cristi, R., and Kjono, O. E., "Analysis/Synthesis of Sound Using a Time-Varying Linear Model," *Proceedings of the International Computer Music Conference*, Aarhus, Denmark, September 1994.

Therrien, C. W., and Hashad, A. I., "The Discrete Wiener Model for Representation of Non-Gaussian Stochastic Processes," presentation and in *Proceedings of the 27th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, pp. 451-455, November 1993.

Therrien, C. W., "Modeling of Passive Sonar Signals (U)," presentation at the 4th Annual ONR Full Spectrum Review, Pennsylvania State University, PA, September 22-25, 1993. [SECRET-NOFORN]

Therrien, C. W., "A Framework for the Modeling of Higher-Order Stochastic Processes," presentation and in *Proceedings of the 8th Workshop on Image and Multidimensional Signal Processing*, Cannes, France, September 1993.

Therrien, C. W., and Hashad, A. I., "Applying the Symmetry Properties of Third Order Cumulants in the Identification of Non-Gaussian ARMA Models," presentation and in *Proceedings of the IEEE Signal Processing Workshop on Higher Order Statistics*, South Lake Tahoe, CA, pp. 101-105, June 1993.

Therrien, C. W., "Signal Modeling for Passive Sonar Data," presentation and in *3rd Annual ONT Full Spectrum Review*, Naval Undersea Warfare Center, New London, CT, 22-25 September 1992. [SECRET-NOFORN]

Therrien, C. W., and Delaney, K. J., "Detecting Abrupt Changes in ARMA Models," *Proceedings of the 25th Asilomar Conf. on Signals, Systems, and Computers*, Pacific Grove, CA, pp. 317-320, Nov. 1991.

Therrien, C. W., and May, G. L., "Comparison of ARMA Modeling Methods in the Time Domain," *Proceedings of the 34th Midwest Symposium on Circuits and Systems*, Monterey, CA, May 1991.

Therrien, C. W., Tummala, M., and Wester, R., "Multidimensional Autoregressive Spectral Estimation Using Iterative Methods," presentation and in the *Proceedings of the 24th Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, November 1990.

Therrien, C. W., Shields, M. K., "Transient Classification Using Markov Methods," in the *Proceedings of the Oceans 90 Conference*, Arlington, VA, September 1990.

Therrien, C. W., and Shields, M. K., "A Hidden Markov Model Approach to the Classification of Acoustic Transients," presentation and in the *Proceedings of the 1990 International Conference Acoustics, Speech, and Signal Processing*, Albuquerque, NM, April 1990.

Therrien, C. W., and Sequeira, A. M., "A New Fast 2-D RLS Algorithm," presentation and in the *Proc. of the 1990 Intl Conf. Acoustics, Speech, and Signal Processing*, Albuquerque, NM, April 1990.

Technical Reports (Additional five reports prepared during 1992-1993)

Therrien, C. W., Frack, K. L., and Kjono, O. E., "Summary Report on Sonar Signal Modeling for FY94 (U), NPS Technical Report EC-94-018, December 1994. [SECRET NOFORN]

Therrien, C. W., Victory, C. W., Pfeifer, G. K., Frank, K. L., and Kjono, O., "Summary Report on Sonar Signal Modeling for FY 1993 (U)," NPS Technical Report EC-93-026, October 1993. [SECRET NOFORN]

Therrien, C. W., "Summary Report on Sonar Signal Modeling," NPS Technical Report, EC-93-001, October 1992. [SECRET-NOFORN]

9. Society membership:

Institute of Electrical and Electronic Engineers (IEEE) and IEEE Acoustics, Speech and Signal Processing Society (Senior Member)
Sigma Xi

10. Awards: Not applicable

11. Courses taught (all are day courses):

Fall 95	EC3410, Discrete-Time Random Signals (4-0) (graduate course)
Winter 95	EC2100 and EC2170, Circuit Analysis (4-2) (undergraduate courses)
Spring 95	EC4410, Speech Signal Processing (3-1) (graduate course)

12. Other duties:

Summer 95	Full time research, reimbursable funding (40 hours per week)
Fall 95	Half time research, reimbursable funding (20 hours per week)
Winter 95	Half time research, reimbursable funding (20 hours per week)

13. Programs attended to improve professional competence:

Associate Chairman for Instruction (includes coordination for professional and continuing education through off-campus short courses and distance learning), 8 hours per week.

14. Not applicable

1. Name and date of birth: **Harold A. Titus**, January 10, 1930

2. Academic rank: Professor (full time)

3. Degrees:

   Ph.D., Engineering Mechanics, Stanford University, Stanford, CA, June 1962
   M.S., Civil Engineering, Stanford University, Stanford, CA, June 1957
   B.S., Mechanical Engineering, Kansas University, Lawrence, KS, June 1952

4. Number of years on faculty: 33

   Original Appointment: Associate Professor, August 1962
   Promotion: Professor, 1970

5. Related experience:

1969-1970	Research, Institute of Geophysics and Planetary Physics, La Jolla, CA
1960-1962	Research, Engineering Department, Stanford University

6. Consulting/patents: None

7. Not registered

8. Principal publications:

   Conference Proceedings/Abstracts/Presentations

   Titus, H., Cooper, C., "Minimum Time Fuel and Sliding Mode Controllers for Spacecraft Altitude Control," presentation and in the *Proceedings of the International Conference of the AIAA on Space Systems*, Huntsville, AL, October 1994.

   Titus, H., Spehn, S., and Cooper, C., "Noise Adaptation and Correlated Maneuver Gating of an Extended Kalman Filter," presentation and in the *Proceedings of the International Symposium on Signal Processing*, Brisbane, Australia, August, 1990.

   Titus, H., Cairns, W., and Cooper, C., "Design of Dynamic Positioning Systems for Buoy and Replenishment at Sea," presentation and in the *Proceedings of the International Conference of Modelling and Control of Marine Craft*, Exeter, England, April 1990.

9. Society member: IEEE, Sigma Xi

10. Awards: None

11. Courses taught (all are day courses):

Winter 95	EO3402, Signal Processing Systems (4-1) (graduate course)
Spring 95	EC4350, Nonlinear Control Systems (4-1) (graduate course)
Fall 95	EC4330/4340, Missile Guidance and Navigation (4-0) (graduate course)
Winter 94	EC3310, Optimal Estimation and Control (3-1) (graduate course)
Spring 94	EC2320, Control Systems (3-0) (undergraduate course)
Fall 94	EC2320, Control Systems (3-0) (undergraduate course)

12. Other duties: None

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not Applicable

1. Name and date of birth: **Murali Tummala**, December 15, 1957

2. Academic rank: Associate Professor (full time)

3. Degrees:

   Ph.D., Electrical Engineering, Indian Institute of Technology, Bombay, India, October 1984
   M.S., Electrical Engineering, Indian Institute of Technology, Bombay, India, July 1981
   B.S., Electronics and Communications Engineering, Institution of Engineers, Calcutta, India, September 1979

4. Number of years on faculty: 9

   Original Appointment: Adjunct Professor, October 1986
   Promotion: Assistant Professor, July 1988
   Associate Professor, July 1990

5. Related experience:

1985-1986	National Research Council Resident Research Associate under Prof. S.R. Parker, Department Electrical and Computer Engineering, Naval Postgraduate School.
1983-1985	Project Engineer, research on signal modeling, Advanced Center for Research in Electronic Indian Institute of Technology, Bombay, India.
1981-1983	Research Scholar under Professor B.V. Rao, Department of Electrical Engineering, Indian Institu of Technology, Bombay, India.
1976-1979	Instructor of Electronics and Communications, undergraduate laboratory instruction, Departme of Electrical Engineering, PES College of Engineering, Mysore University, Mandya, India.

6. Consulting/patents: None

7. Not registered

8. Principal publications:

   Journal Papers

   Siomacco, E. M., and Tummala, M., "Parametric Modeling of Integrated Circuit Interconnections," *IEEE Transactions on Circuits and Systems, II: Analog and Digital Signal Processing*, Vol. 39, No. 6, pp. 377-382, June 1992.

   Richter, D. A., and Tummala, M., "Iterative System Identification Using Multigrid Techniques," *Electronics Letters* (IEE Publication), Vol. 28, No. 4, pp. 433--435, February 1992.

   Tummala, M., "New Algorithm for Solving Block Matrix Equations with Applications in 2-D AR Spectral Estimation," *IEEE Transactions on Signal Processing*, Vol. 39, No. 3, pp. 759-764, March 1991.

   Tummala, M., "Efficient Iterative Methods for FIR Least-Squares Identification," *IEEE Transactions, Acoustics, Speech, and Signal Processing*, Vol. ASSP-38, No. 5, pp. 887-890, May 1990.

   Conference Proceedings/Abstracts/Presentations

   Watkins, B. E., and Tummala, M., "Classification Vector Quantization of Image Data Using Competitive Learning," in *Proc. of 1st IEEE International Conf. on Image Processing*, Austin, TX, Nov. 1994.

   Erdemir, A., Carvalho, R. M., and Tummala, M., "Data Compressing Using Wavelet Transforms and Vector Quantization," in *Proc. of 37th Midwest Symp. on Circuits and Systems*, Lafayette, LA, Aug. 1994.

   Garcia, R. E., Fallon, M. P., and Tummala, M., "Memory Neural Network Algorithm for Missile Control," in *Proceedings of the 37th Midwest Symposium on Circuits and Systems*, Lafayette, LA, August 1994.

   Tummala, M., and Wood, J. D., "A Multi-Input Multi-Output Recursive Least Squares Algorithm with Applcations to LORAN-C Transmitter," in *Proceedings of the IEEE International Symposium on Circuits and Systems*, London, June 1994.

   Walker, T. O., Tummala, M., and Voigt, R., "An Adaptive Resonance Theory (ART) Neural Network for Synthetic Aperture Radar Target Recognition and Classification," in *Proceedings of the World Congress on Neural Networks*, San Diego, CA, June 1994.

   Fallon, M. P., Garcia, R. E., and Tummala, M., "Nonlinear Missile Controller Using Memory Neural NAtworks," in *Proceedings of the World Congress on Neural Networks*, San Diego, CA, June 1994.

Frazier, S., Parimuha, E., and Tummala, M., "Waveform Bounding and Combination Techniques for Direct Drive Testing," in *Proceedings of the EUROEM-94 Symposium on Electromagnetic Environments and Consequences*, Bordeaux, France, June 1994.

Frazier, S., Parimuha, E., and Tummala, M., "EMP Waveform Analysis and Combination Techniques," presented at 1994 HEART Conference, NPS, Monterey, CA, February 1994.

Tummala, M., and Richter, D. A., "Iterative System Modeling Using Multigrid Techniques," presentation and in *Proceedings of IEEE International Symposium on Circuits and Systems*, Chicago, IL, May 1993.

Bruckner, D. C., Tummala, M., and Kmiecik, G. A., "A Computer Simulation for Pulse Shape Control of the AN/FPN-42 and AN/FPN-44B Loran-C Transmitters," presentation and in *Proceedings of the Wild Goose Association Symposium*, Santa Barbara, CA, October 1993.

Bruckner, D. C., and Tummala, M., "Automatic Pulse Shaping with the AN/FPN-42 and AN/FPN-44B Loran-C Transmitters," presentation and in *Proceedings of the Wild Goose Association Symposium*, Santa Barbara, CA, October 1993.

Bruckner, D. C., and Tummala, M., "Nonlinear, Time-Varying Model of the AN/FPN-42 Loran-C Transmitter," presentation and in *Proceedings of IEEE International Conference on Circuits and Systems*, Chicago, IL, May 1993.

Parker, R. E., Jr., and Tummala, M., "Identification of Volterra Systems with a Polynomial Network," in *Proc. of IEEE International Conf. on Acoustics, Speech, Signal Processing*, San Francisco, Mar. 1992.

Watkins, B. E., and Tummala, M., "Multiple Stage Vector Quantization Using Competitive Learning," in *Proceedings of the IEEE International Symposium on Circuits and Systems*, San Diego, CA, May 1992.

Tummala, M., and Eremic, J. C., "Iterative Methods for Estimation of 2-D AR Parameters Using a Data-Adaptive Toeplitz Approximation Approach," *Proceedings of the 25th Asilomar Conference on Signal, Systems, and Computers*, Pacific Grove, CA, November 1991.

Tummala, M., and MacHardy, W. R., "Adaptive Algorithm for IIR Filtering Based on Matrix Iterative Techniques," *Proc. of IEEE International Symp. on Circuits and Systems*, Singapore, June 1991.

Technical Reports

Tummala, M., Therrien, C. W., and Herdegen, D. W., "Adaptive Noise Cancellation Applied to NUWC Test Ranges," NPS Technical Report, EC-93-003, November 1992.

Therrien, C. W., Tummala, M., and Wellington, C. H., "Application of a Back Propagation Neural Network for Noise Cancellation," NPS Technical Report, EC-93-002, November 1992.

Therrien, C. W., Scout, J. B., and Tummala, M., "Detection of BPSK Signals Using the ESPRIT Method," NPS Technical Report, EC-92-008, August 1992.

9. Society member: Institute of Electrical and Electronics Engineers, Acoustics, Speech and Signal Processing Circuits an Systems, Eta Kappa Nu

10. Awards:

John J. Schieffelin Award for Excellence in Teaching, 1991, Naval Postgraduate School.
Commendation for excellence in teaching during the academic years 1987, 1988, 1989, 1990, Naval Postgraduat School, Monterey, CA.

11. Courses taught (all are day courses):

Fall 95	EC2400, Discrete Systems, 2 sections (3-2) (undergraduate course)
Summer 95	EC4960, Artificial Neural Networks (3-0) (graduate course)

12. Other duties:

Summer 95	Half time research on a grant from NAWC (20 hours per week)
Spring 95	Full time research on a grant from U.S. Coast Guard (40 hours per week)
Winter 95	Full time research on a grant from SPAWAR SYSCOM (40 hours per week)

13. Programs attended to improve professional competence: Attended two courses on Computer Networks: EC3850 (Fa 1994) and EC4850 (Summer 1994)

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Donald van Z. Wadsworth**, July 14, 1931

2. Academic rank: Senior Lecturer (full-time)

3. Degrees:

   Ph.D., Geophysics, M.I.T., Cambridge, MA, 1958
   B.A., Physics, Williams College, Williamstown, MA, 1953

4. Number of years on faculty: 7

   Original appointment: Adjunct Professor, May 1988
   Joint Appointment (ECE and C3I): 1994

5. Related experience:

1978-1987	Hughes Aircraft Company. Systems engineering/analysis/testing for radar missile seekers, SI interceptors/seekers, and communications satellites. Principal investigator for solar plasm experiments. IR&D project leader for MMW seeker technology. Taught Satellite Communication Systems Engineering course to graduate engineers.
1975-1978	Consultant in digital/data networks.
1958-1975	Bell Telephone Laboratories. Department Head. Systems engineering and hardware/softwar development for communications, missile guidance and control (Apollo, Titan) and anti-submarin warfare surveillance systems. Taught Professional Engineering Review Course to graduat engineers.

6. Consulting/patents: Consultant to NAS; 2 patents

7. Registered in California (expired)

8. Principal Publications:

   Technical Reports

   Wadsworth, D. v. Z., "Automated Performance Evaluation Technique for Cryptologic Sites: MAPS User's Manual (U)," NPS Technical Report EC-95-003, February 1995.

   Wadsworth, D. v. Z., O'Reilly, T. C. and Powell, J. R., Airborne EW vs. Space-Based C3 Systems (U), NPS Technical Report EC-94-003, May 1994.

9. Society member: IEEE (Senior Member), AFCEA, AOC

10. Awards: None

11. Courses taught (all courses are graduate level day courses):

Summer 95	EO3512, Communications and Countermeasures (3-2)
Winter 95	EO3513, Communications Systems Engineering: Modulation (4-2)
	EO3502, Space Power and Radiation Effects (3-1)
Fall 94	CC4750, Military Communications for C4I Systems (3-1)

12. Other duties:

   Member, Faculty Search Committee
   Supervised four M.S. theses (2 hours per week)

   Research

Spring 95 & Fall 94	PI, Half time research, "Communications Vulnerability to Jamming" sponsored by OPNAV N64E and NAVSECGRU

13. Programs attended to improve professional competence:

   Armed Forces Staff College
   Joint C2 Staff and Operations Course

14. Special duties of co-op faculty: Not applicable

1. Name and date of birth: **Xiaoping Yun**, February 15, 1962

2. Academic rank: Associate Professor (full time)

3. Degrees:

   D.Sc., Systems Science and Mathematics, Washington University, St. Louis, MO, 1987
   M.S., Systems Science and Mathematics, Washington Univeristy, St. Louis, MO, 1984
   B.S., Electrical Engineering, Northeastern University, China, 1982

4. Number of years on faculty: 0.5

   Original appointment: Associate Professor, 1994

5. Related experience:

   1987-1994 Assistant Professor, Department of Computer and Information Science, University of Pennsylvani
   1982-1987 Research Assistant, Washington University, St. Louis, MO

6. Consulting/patents: None

7. Not registered

8. Principal publications:

Journal Papers

Paljug, E., and Yun, X., "Experimental Study of Two Robot Arms Manipulating Large Objects," *IEEE Transactions on Control Systems Technology*, June 1995.

Paljug, E., and Yun, X., and Kumar, V., "Control of Rolling Contacts in Multi-Arm Manipulation," *IEEE Transactions on Robotics and Automation*, Vol. 10, No. 4, August 1994.

Yamamoto, Y., and Yun, X., "Coordinating Locomotion and Manipulation of a Mobile Manipulator," *IEEE Transactions on Automatic Control*, Vol. 39, No. 6, June 1994.

Sarkar, N., Yun, X., and Kumar, V., "Control of Mechanical Systems with Rolling Constraints: Applications to Dynamic Control of Mobile Robots," *International Journal of Robotics Research*, Vol. 13, No. 1, pp. 55-69, February 1994.

Caraza, J.-A. N., and Yun, X., "Force-Closed Grasping with Two Hands," *Journal of Robotic Systems*, Vol. 10, No. 7, pp. 973-990, October 1993.

Yun, X., "Object Handling Using Two Arms Without Grasping," *International Journal of Robotics Research*, Vol. 12, No. 1, pp. 99-106, February 1993.

Yun, X., "Dynamic State Feedback Control of Two Cooperative Manipulators," *International Journal of Systems Science*, Vol. 24, No. 5, pp. 915-928, 1993.

Xu, Y., Yun, X., and Paul, R. P., "Motion and Force Control of Robot Manipulator and Compliant Wrist," *International Journal of Robotics and Automation*, Vol. 7, No. 2, pp. 57-63, 1992.

Kobayashi, H., Yun, X., and Paul, R., "Stability of Randomly Sampled Robotic Systems," *Journal of the Robotics Society of Japan* (in Japanese), Vol. 10, No. 1, pp. 99-106, 1992.

Xu, Y., Yun, X., and Paul, R. P., "Nonlinear Feedback Control of Robot Manipulator and Compliant Wrist," *Dynamics and Control*, No. 1, pp. 325-339, 1991.

Yun, X., and Cheng, D., "Input-Output Decoupled Linearization of General Nonlinear Systems," *Transactions of the Institute of Measurement and Control*, Vol. 13, No. 4, pp. 218-224, 1991.

Yun, X., "Modeling and Control of Two Constrained Manipulators," *Journal of Intelligent and Robotic Systems*, No. 4, pp. 363-377, 1991.

Yun, X., and Kumar, V. R., "An Approach to Simultaneous Control of Trajectory and Interaction Forces in Dual Arm Configurations," *IEEE Transactions on Robotics and Automation*, Vol. 7, No. 5, pp. 618-625, October 1991.

Tarn, T. J., Bejczy, A. K., Yun, X., and Li, Z., "Effect of Motor Modeling on Robot Arm Control," *IEEE Transactions on Robotics and Automation*, Vol. 7, No. 1, pp. 114-122, February 1991.

9. Society member: Institute of Electrical and Electronics Engineers (IEEE)

10. Honors and awards: None

11. Courses taught (all are day courses):

Winter 95	EC2300, Control Systems (3-2) (undergraduate course)
Fall 95	EC3500, Analysis of Random Signals (4-0) (graduate course)

12. Other duties:

1 Sep 94- 31 Dec 95	Half time research, "Coordination of Mobile Manipulators," sponsored by NSF.

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

1. **Name and date of birth: Lawrence J. Ziomek**, August 8, 1949

2. **Academic rank: Professor (full-time)**

3. **Degrees:**

   Ph.D., Acoustics, The Pennsylvania State University, University Park, PA, November 1981
   M.S., Electrical Engineering, The University of Rhode Island, Kingston, RI, January 1974
   B.E., Electrical Engineering, Villanova University, Villanova, PA, May 1971

4. **Number of years on faculty: 13**

   Original Appointment: Assistant Professor, May 1982
   Promotion: Associate Professor, July 1986
   Promotion: Professor, July 1995

5. **Related experience:**

Sep. 1976- Apr. 1982	Research Assistant, Department of Ocean Technology, Applied Research Laboratory, The Pennsylvania State University, State College, PA
Nov. 1973- May 1976	Member of Technical Staff, TRW Systems Group, Redondo Beach, CA

6. Consulting/patents: None

7. Not registered

8. Principal Publications:

Journal Papers

Ziomek, L. J., "Sound-Pressure Level Calculations Using the RRA Algorithm for Depth-Dependent Speeds of Sound Valid at Turning Points and Focal Points," *IEEE Journal Oceanic Engineering*, Vol. 19, pp. 242-248, 1994.

Ziomek, L. J., "Three Necessary Conditions for the Validity of the Fresnel Phase Approximation for the Near-Field Beam Pattern of an Aperture," *IEEE Journal of Oceanic Engineering*, Vol. 18, pp. 73-75, 1993.

Ziomek, L. J., and Polnicky, F. W., "The RRA Algorithm: Recursive Ray Acoustics for Three-Dimensional Speeds of Sound," *IEEE Journal of Oceanic Engineering*, Vol. 18, pp. 25-30, 1993.

Ziomek, L. J., and Brackenridge, R. P., "Estimation of the Spherical Coordinates of Multiple Broadband Targets via Adaptive Beamforming and Nonlinear Least Squares," *Journal of the Acoustical Society of America*, Vol. 91, pp. 2799-2804, 1992.

Ziomek, L. J., "Comments on the Relationships Between Linear Systems Theory and the Free-Space Solution of the Inhomogeneous Linear Wave Equation," *Journal of the Acoustical Society of America*, Vol. 88, pp. 2027-2030, 1990.

Conference Proceedings/Abstracts/Presentations

Ziomek, L. J., "Sound-Pressure Level Calculations Along Individual Ray Paths Using the RRA Algorithm," *International Conference on Theoretical and Computational Acoustics*, Mystic, CT, Session 7.1 Rays and Beams I (**Invited Paper**), July 5-9, 1993.

Ziomek, L. J., "Sound-Pressure Level Calculations Using the RRA Algorithm for Depth-Dependent Speeds of Sound Valid at Turning Points and Focal Points," 125th Meeting of the Acoustical Society of America, May 17-21, 1993, Ottawa, Ontario, Canada, *Journal of the Acoustical Society of America*, Vol. 93, No. 4, Pt. 2, p. 2425.

Ziomek, L. J., "Recursive Ray Acoustics for Three-Dimensional Sound-Speed Profiles," 123rd Meeting of the Acoustical Society of America, Salt Lake City, UT, May 11-15, 1992, *Journal of the Acoustical Society of America*, Vol. 91, No. 4, Part 2, p. 2391.

Ziomek, L. J., "Linear Systems Theory and its Relationship to Ocean Acoustics," 120th Meeting of the Acoustical Society of America, November 26-30, 1990, San Diego, CA, *Journal of the Acoustical Society of America*, Suppl. 1, Vol. 88, p. S37 (**Invited Paper**).

Ziomek, L. J., "LSVOCN: A Pulse-Propagation Model for a Linear, Space-Variant Ocean," 119th Meeting of the Acoustical Society of America, May 21-25, 1990, The Pennsylvania State University, University Park, PA, *Journal of the Acoustical Society of America*, Suppl. 1, Vol. 87, pp. S130-S131.

9. Society member:

The Institute of Electrical and Electronic Engineers (IEEE) (Senior Member)
The Acoustical Society of America (ASA)
Sigma Xi

10. Awards:

Naval Postgraduate School, Certificate of Recognition for Outstanding Instructional Performance in 1993.
Villanova University, College of Engineering Professional Achievement Award (1988).
The Pennsylvania State University, Graduate Programs in Acoustics, Kenneth T. Simowitz Memorial Award for *outstanding effort in publishing research results* (1982).
Eta Kappa Nu, Tau Beta Pi, Sigma Xi, Phi Kappa Phi
Illinois State Scholarship

11. Courses taught this year (all courses are graduate level day courses):

Spring 95	EC4970, Bionic Sonar (3-0)
Winter 95	EC4450, Sonar Systems Engineering (4-1)
Fall 95	EC3450, Fundamentals of Ocean Acoustics (4-0)

12. Other duties:

Spring 95	Half-time research (20 hours per week)
Winter 95	Half-time research (20 hours per week)
Fall 95	Half-time research (20 hours per week)

13. Programs attended to improve professional competence: None

14. Special duties of co-op faculty: Not applicable

Ziomek, L. J., "Recursive Ray Acoustics for Three-Dimensional Sound-Speed Profiles," *Naval Research Reviews*, One/1992, Vol. XLIV, pp. 54--55, 1992.

Ziomek, L. J., "Recursive Ray Acoustics Algorithm," presented at the Surface ASW Advanced Development and Submarin
Combat System Advanced Development Joint Program Review, Naval Undersea Warfare Center (NUWC), New Londo
CT, 31 January 1994-4 February 1994.

Ziomek, L. J., "Sound-Pressure Level Calculations Along Individual Ray Paths Using the RRA Algorithm," presentatio
at the Mathematics and Scientific Computing Colloquium, Department of Mathematics, Naval Postgraduate Schoo
September 9, 1993.